The Pennsylvania State University

The Graduate School

Development of Task Statements and Standards for Water and Wastewater Treatment Plant Maintenance

A Report in

Environmental Engineering

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Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Engineering

December 1985

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INTRODUCTION

The supply of safe potable water and the proper treatment and disposal of the resultant sewage are services that impact everyone. Consequently, costs for construction, operation, and maintenance of the necessary treatment facilities are borne by all who receive service, either directly or indirectly. Construction costs usually are funded through government grants and bonding. Competitive bidding and agency overviews tend to keep those costs under control without limiting them unduly. However, costs of operations and maintenance usually are the responsibility of the local owner (ie. authority, municipality, etc.) and normally are funded through service charges assessed to the consumers. Without a rigid system in place to dictate operations and maintenance levels, the only forces acting on the owners generally are those of the consumers, ie. a desire for the lowest possible rate.

Webster states that maintenance is the upkeep of property and equipment in a state of efficiency. Looked at in another way, maintenance is the act of keeping property and equipment in the same condition it was yesterday. That

definition is the crux of the problem, as there is little evidence that the work that has been accomplished justified the expenditures made. The rate of deterioration is often times slow enough that deferral of maintance can be an accepted course of action for many years. The incidence of breakdowns and process interruptions gradually increases to the point that major overhaul or replacement is necessary. The irony of the situation is that the manager of the facility during the period of deferred maintenance is very highly thought of because of his success in keeping current operating costs down. Higher level management does not realize that, in actuality, he is consuming their capital investment by deferring maintenance expenditures.

The function of management is to obtain the most return for the least investment. Normally, the only costs included in the equation are those that are experienced during the fiscal calendar. Deferred maintenance is not included unless there has been a conscious effort to quantify its value. However, the oil filter advertisement that said "you can pay me now or pay me later" is very true. The deferred maintenance costs will be paid eventually, and probably at a very high rate.

The purpose of this paper is to develop a series of labor hour standards

that can be applied to maintenace and repair actions on water and wastewater treatment plant equipment. Through application of the appropriate standards, a manager will be able to estimate the yearly cost of maintenance (both preventative and corrective) for his facilities. The system developed as part of this project will provide documentation that can be used to justify budget requests, staffing, and quantify the impact that deferred maintenance will have in future budgets. The standards also can be used to evaluate employee efficiency and identify deficiencies in supervision and training that otherwise would go unrecognized.

LITERATURE REVIEW

A review of the literature has revealed no published standards for the maintenance and repair tasks that are developed later in this paper. There is substantial evidence in the literature to indicate that maintenance and repair has not been sufficient to maintain plants in many cases. The national desire to have clean rivers, lakes, and streams has resulted in massive programs to build treatment plants that are designed to remove contaminants from waste streams prior to discharge into a receiving body of water. The Government Accounting Office has reported that, as of December 1979, almost 18,000 plants, representing a federal government investment of 25 billion dollars and several billion dollars more from State and local governments, were in operation or under construction.[1] This huge investment in capital by Federal and State governments in futherence of National policy has been turned over to local municipalities and sewer authorities to maintain and operate. By the late 1970's, it was becoming obvious that an increasing number of treatment plants were failing to perform as expected. In a white paper on operation and maintenance of water pollution control facilities, the Water Pollution Control Federation (WPCF) found that emphasis in this area had

been greatly overlooked in the haste to get waste treatment systems in place and on-line.[2] They recommended that owners should require a realistic updated cost of operations and maintenance from the design consultant both at the time 50 percent of the construction is completed and prior to the last budget cycle before the system is ready for operation.[3]

In a comprehensive study by EPA of 103 facilities, a total of 70 potential problem areas (10 of which were maintenance) were weighed and ranked for severity of impact on performance.[4] While a maintenance factor was the leading cause of poor performance in only one plant, it was a contributing factor noted in at least twenty percent of the plants studied. One of the recommendations made as a result of the study was that budgeting for operation and maintenance of wastewater treatment facilities must become organized and a higher priority in municipal budgets.[5]

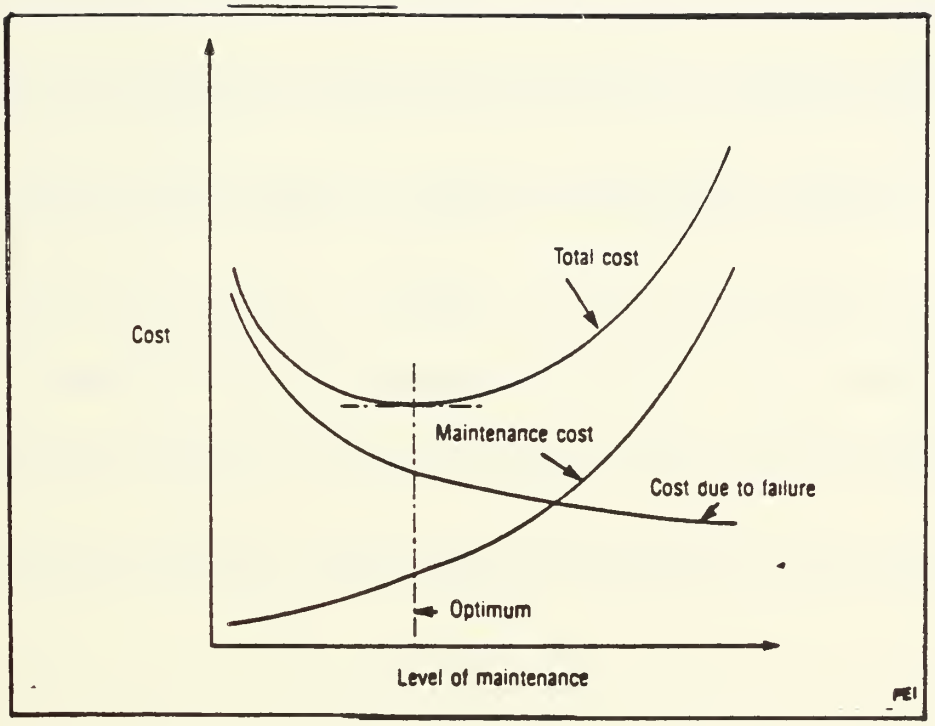
The AWWA Committee on Job Measurement Standards reported on the methods and benefits of applying standards to water utilities operations in 1979.[6] They gave no actual standards to use, but described methods to be used for development of standards. The report did indicate that the benefits to be gained by using standards included increased productivity, better collection of cost data, and discovery of new work methods. Productivity

was improved because management was able to effect better coordination, maintain continuous operations and obtain better utilization of the available manpower. Better collection of cost data and discovery of new work methods resulted from comparison of actual work to estimated work.

There is much evidence to support the theory that improved management of maintenance can save money. As early as 1971, the City of Philadelphia Water Department instituted a systemized approach to maintenance with time standards and found an annual savings in excess of $318,000 after two years.[7] An outside consultant was hired to develop time standards that were tailored to their plant. Both the Los Angeles County Flood Control District[8] and Colorado Springs[9] found that new maintenance management systems have been instrumental in reducing maintenance budgets without reducing services or output. The City of Wausau, Wisconsin found that, by hiring a professional firm to operate the plant and schedule maintenance, it was able to reduce down time and end a series of permit violations.[10] Industry also has found that maintenance management is important. A metal processing facility[11], Monsanto and Chemplex chemical plants in England[12], and Corning Glass Works[13] have all found that, by installing maintenance management systems, costs and equipment down times are reduced.

There has been some concern that, with the improved maintenance management systems being implemented, it is possible to go overboard and expend funds performing unnecessary maintenance. It has been reported that an increased level of maintenance should reduce the costs incurred due to failure.[14] However, there is a point where a higher level of maintenance does not result in a proportionate reduction in the costs due to failure and total expenditures start to rise. Figure 1 graphically depicts the relative relationship. The level of maintenance is based on the frequency of maintenance. More frequent accomplishment of preventive maintenance work, such as greasing and oil checks, is considered a higher level of maintenance. As tasks are performed more frequently, the cost to accomplish the maintenance rises, but the likelihood of failure of the component will decrease. The costs due to failure decrease rapidly as the level of maintenance is increased from zero to the manufacturers recommended levels. Beyond that point it levels out. When both maintenance costs and costs due to failure are added for a given level of maintenance, it can be seen that there is a level of maintenance that will minimze costs. Instrumentation equipment may be a type that is likely to be subject to over maintenance.[15,16]

FIGURE 1



Relation of Costs to Maintenance Levels

from Petroleum Engineer International[14]

The goal of this project was to produce a set of labor hour and frequency standards that can be applied to maintenance, repair, and replacement of equipment and appurtenences used in water and wastewater treatment. As indicated in the previous section, a diligent search of the literature revealed no published reports that had accomplished such a task. A list of the tasks to be considered was compiled, a system to number and store the information was developed, and estimates of labor hours and frequency of occurrence were made.

a. Development of a List of Tasks.

Water and wastewater treatment consists of a series of unit operations designed to deliver an effluent with the desired qualities. The most logical way to compile the data is on the basis of unit operations. Different plants will have a different combination of unit operations and vessel sizes depending on the influent characteristics and effluent qualities desired, but the equipment necessary for each unit operation is basically the same.

A complete list of unit operations that are used in water and wastewater

treatment (Table 1) was compiled. Not all unit operations listed would be encountered in any one plant, but the list is inclusive of unit operations that have been and are being used to treat water and wastewater streams. Two areas that were not included are incineration of sludge and final disposal of sludge , ie. landfilling or spraying on agricultural lands. It was felt that those areas are outside the basic scope of this study.

Each of the unit operations listed was reviewed in detail and any equipment or appurtenance that might be necessary for that operation was listed. For example, under the unit operation called sludge pumping, there were five different types of pumps listed (plunger, centrifugal, rotary, diaphragm, and grinder) because any of these pumps might be used for that purpose. In any one plant handling sludge, there often would be only one type of sludge pump installed, but that particular pump could be any of the five listed types depending on the characteristics of the sludge, volume of flow, head, and designer preferences. For the purposes of this study, each of the pieces of equipment and various appurtenances were defined as a component. Appendix A contains a list of the components considered in this study. One may note that there are many components that were listed more than once in Appendix A. That situation occurred because there are some components, such

TABLE 1

LIST OF UNIT OPERATIONS TO BE CONSIDERED

WASTEWATER TREATMENT

- PRIMARY
  - SCREENING
  - GRINDING
  - FLOW METERING
  - PRIMARY SETTLING
  - SLUDGE HANDLING
  - SCUM REMOVAL
- SECONDARY
  - AERATION
  - AIR DELIVERY
  - SECONDARY CLARIFIERS
  - CHEMICAL TREATMENT
  - RETURN SLUDGE
  - EXCESS SLUDGE HANDLING
  - SCUM REMOVAL
  - CHLORINATION
  - EFFLUENT WATER SAMPLING
  - EFFLUENT WATER METERING
  - TRICKLING FILTER
  - ROTATING BIOLOGICAL CONTACTOR EQUIP
  - FILTRATION
- TERTIARY
  - NITROGEN REMOVAL
  - PHOSPHORUS REMOVAL
- SLUDGE HANDLING
  - INCINERATIORS
  - VACUUM FILTRATION
  - SLUDGE CONDITIONING
  - CHEMICAL TREATMENT
  - SLUDGE THICKENING
  - SLUDGE DIGESTORS
  - CENTRIFUGE EQUIPMENT

WATER TREATMENT

- PUMPING EQUIPMENT
- MIXING
- FLOCCULATION
- FILTRATION
- CHLORINATION
- ION EXCHANGE
- ACTIVATED CARBON COLUMN

as motors, that are used in many different unit operations. They were listed only once per unit operation, but were included in every unit operation in which they are found. In this way, a complete list of components can be assembled if the unit operations to be used are known.

Each component listed was analyzed to determine the types of tasks that would have to be accomplished over the life of the component to keep it in operating condition. Sources of information used included manufacturer's maintenance instructions, existing treatment plant operations and maintenance manuals, treatment plant mechanics (through interviews), manuals of practice, and personal inspection of some of the equipment by the author. Two water treatment plants and four sewage treatment plants were visited by the author to conduct interviews with mechanics, review equipment maintenance cards and conduct inspection of equipment. The tasks were compiled into a list on the basis of unit operation. This list is presented in Appendix B.

b. Numbering and Data Base System.

A seven digit numbering system was applied to the list giving each task statement a unique number. The numbering system used was one specified by

the Army Civil Engineering Research Laboratory (CERL), the financial sponsor for this project. The first four digits refer to the type of treatment plant, ie. 1616xxx is for water treatment plants and 1624xxx is for wastewater treatment plants. The fifth digit refers to the unit operation. The numbers one through nine were used for this, the sixth, and the seventh digits. The number zero was not used to avoid confusion in submittals to CERL. Because there were more than nine unit operations, after the number nine, letters were used sequentially starting with "A" and going to "Z". Letters were allowed to be used in any digit and were needed with most of them. The sixth digit refers to the component and values were assigned sequentially as the components were determined for the unit operation under study. Because of the number of components, it was not possible to always list motors as "1" and centrifugal pumps as "2", for example. The seventh digit refers to the task statement. Readers should note that the there are what may appear to be missing task statements in Appendix B. These appparent omissions were proposed tasks that were deleted during the study for lack of applicability. This numbering system is somewhat cumbersome to use and does not allow for grouping by level of treatment, ie. primary, secondary, tertiary, etc., but was used because it was mandated by the project sponsor.

There are more than six hundred task statements for the water and wastewater treatment plants. It would be very time consuming and tedious to keep track of all the information required without the use of a computerized data base. For this project, a relational data base called D-Base III by Ashton-Tate, Inc. was used. A routine developed by the Architectural Engineering Department of the Pennsylvania State University for the CERL project on plumbing and electrical systems was modified for use in this project. The routine develops reports in the format that CERL requires, but is flexible enough to allow output in a variety of formats. The computer used was an IBM-PC/XT with a 10 megabyte hard disk. Appendix C lists the directions for use of the system including input and output of data.

c. Frequency and Labor Hour Estimates.

For each task statement, the ultimate goal is to have an estimate for the labor hours, equipment, and materials necessary to accomplish the task and frequency of occurence of the task. The only data the author found readily available for the tasks on water and wastewater treatment equipment were that for frequency of preventive maintenance. There are no published data on

estimated labor hours, equipment, or materials for any of the tasks and there are no industry accepted standards on the life expectancy of equipment. Letters were sent to firms that provide automated maintenance systems; a sample letter is included in Appendix D, but no firm was able to list a reference that had been using its system long enough so that they considered their data to be of any value for use in this project. Most firms responded that their systems were new and had not been put in place yet.

Labor hours were selected as the first parameter to study in detail. Rather than trying to determine every unknown for every task statement, if all labor hours were estimated at once there would be more consistency and efficiency in providing this information. Labor hours for each task were estimated using several sources for guidance, a list of which is provided in Appendix E. The reference number for each source listed in Appendix E is the labor reference noted in the task statement record in the computer data base. Most of the estimates were developed using one or more of the Engineered Performance Standards (EPS) manuals written by the Department of Defense. See Appendix E for a list of the specific manuals used. These manuals were designed to aid in estimating labor hours for maintenance and repair of DOD's real property (buildings and grounds). There were very few tasks that were

directly listed. Estimates were developed by using the estimated times for similar actions. The EPS manuals list a task and time and then break the time estimate into the several steps (each individually estimated) necessary to complete the task, see Figure 2 for an example. In many cases, all steps in the EPS task were not needed for the task statement being estimated, but the author was able to apply some of the steps to a water and wastewater task statement to develop an estimate. There is a memo field in every record in the data base that details and references how the estimated labor hours, frequency, equipment, or materials were determined. After all the information possible was gleaned from the EPS manuals, other sources were used to estimate labor hours. The author was not able to estimate labor hours for every task listed because the information necessary to accomplish this effort was not available. Frequencies for some of the task statements were estimated and documented in the same manner that the labor hours were done. However, due to lack of time, only approximately 10 percent of the task statements had frequencies estimated and no material or equipment estimates were developed. A sample task statement data form is shown in Figure 3.

Figure 2

NT-198 REMOVE AND INSTALL MOTOR FROM CENTRIFUGAL SUMP PUMP. REMOVE AND INSTALL PUMP SHAFT PACKING, SHAFT BEARING, SHAFT OR IMPELLER IN SHOP. MOVING PUMP TO SHOP NOT INCLUDED.

NO	REFERENCE	WORK UNIT DESCRIPTION	HOURS	UNITS	V38
1	PWMU-1-8000	REMOVE 4 SCREWS FROM SWITCH COVER PLATE.	.03508	JOB	
2	PWMU-1-8005	REMOVE SWITCH COVER PLATE.	.00198	JOB	
3	PWMU-1-8006	DISCONNECT WIRES AT 3 TERMINALS.	.02013	JOB	
4	PWMU-1-8000	REMOVE 2 SWITCH BRACKET SCREWS.	.01754	JOB	
5	PWMU-1-8010	REMOVE SWITCH ASSEMBLY.	.01265	JOB	
6	PWMU-1-8013	REMOVE FLOAT ROD SPRING RETAINER PIN.	.02252	JOB	
7	PWQ-19-I	UNSCREW MOTOR FROM PUMP TUBE.	.06763	JOB	
8	PWMU-1-8021	INSERT FLOAT ROD THROUGH MOTOR END BELL GUIDE HOLE AND FLOAT ROD SPRING.	.02412	JOB	
9	PWMU-1-8010	INSTALL SPRING RETAINERS OVER FLOAT ROD END.	.02530	JOB	
10	PWMU-1-8010	ENGAGE SPRING COUPLING WITH SLOT IN MOTOR SHAFT.	.01265	JOB	
11	PWQ-19-I	SCREW MOTOR ON TO PUMP TUBE.	.06763	JOB	
12	PWMU-1-8013	INSTALL FLOAT ROD RETAINER PIN.	.02252	JOB	
13	PWMU-1-8010	INSTALL SWITCH ASSEMBLY.	.01265	JOB	
14	PWMU-1-8000	INSTALL 2 SWITCH BRACKET SCREWS.	.01754	JOB	
15	PWMU-1-8006	CONNECT WIRES AT 3 TERMINALS.	.02013	JOB	
16	PWMU-1-8005	INSTALL SWITCH COVER PLATE.	.00198	JOB	
17	PWMU-1-8000	INSTALL 4 COVER PLATE SCREWS.	.03508	JOB	
18	PWMU-1-8013	REMOVE IMPELLER SHAFT DRIVE PIN.	.02252	JOB	
19	PWMU-1-8000	LOOSEN IMPELLER SHAFT COUPLING ADAPTER COLLAR SET SCREW.	.00877	JOB	
20	PWMU-1-8000	REMOVE IMPELLER SHAFT COUPLING ADAPTER COLLAR.	.00877	JOB	
21	PWMU-1-8000	REMOVE 4 SCREWS ON PUMP BASE TO PUMP HOUSING.	.03508	JOB	
22	PWMU-1-8005	REMOVE PUMP BASE.	.00198	JOB	
23	PWMU-1-8000	REMOVE 4 PUMP HOUSING PLATE SCREWS.	.03508	JOB	
24	PWMU-1-8010	REMOVE PUMP HOUSING PLATE.	.01265	JOB	
25	PWMU-1-8011	REMOVE IMPELLER SHAFT AND IMPELLER, SHAFT ADAPTER AND IMPELLER SHAFT BELL BEARING.	.03618	JOB	
26	PWMU-1-8000	REMOVE PUMP BEARING.	.00877	JOB	
27	PWMU-1-8013	REMOVE PUMP BEARING PACKING GLAND RETAINER.	.02252	JOB	
28	PWMU-1-8010	REMOVE PUMP BEARING PACKING GLAND.	.01265	JOB	
29	PWMU-1-8005	REMOVE PUMP BEARING PACKING, SPRING AND WASHER.	.00594	JOB	
30	PWMU-1-8005	ASSEMBLE PUMP BEARING PACKING GLAND WITH NEW PACKING (4 RINGS), SPRING AND WASHER.	.01188	JOB	
31	PWMU-1-8010	INSTALL PUMP BEARING PACKING GLAND AND RETAINER INTO BEARING.	.02530	JOB	
32	PWMU-1-8000	INSTALL PUMP BEARING INTO PUMP TUBE.	.00877	JOB	
33	PWMU-1-8013	REMOVE IMPELLER PIN.	.02252	JOB	
34	PWMU-1-8013	REMOVE IMPELLER FROM SHAFT.	.02252	JOB	
35	PWMU-1-8013	ASSEMBLE IMPELLER, IMPELLER SHAFT AND IMPELLER PIN.	.04504	JOB	
36	PWMU-1-8013	INSTALL IMPELLER SHAFT INTO PUMP TUBE.	.02252	JOB	
37	PWMU-1-8010	INSTALL IMPELLER SHAFT BALL BEARING RETAINER.	.01265	JOB	

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Example of Engineered Performance Task

TASK DATA FORM

Task Code: 0811101

Component: TANK-LESS WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: M/R REPLACE FLUSH VALVE
Unit of Measure: 1-CT Frequency of Occurrence: H: 8.00 A: 10.00 L: 12.00
Persons per Team: 1 Task Duration: 0.117 Trade: 3
References: Labor: 2 Material: 1 Equipment: 1

Labor Resources

Subtask Description	Labor Hrs
REMOVE OLD FLUSH VALVE	
INSTALL NEW FLUSH	0.090
VALVE (QT-311 TWICE).	

Material Resources

Description	Quantity	Unit Cost	Total Cost	Equiv Labor Hrs
Material	0.00	0.00	0.11	0.0082
	0.00	0.00	0.03	0.0020

FIGURE 3

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	LH	0.090	0.027	0.117
Material	ELH	0.010	0.003	0.013
Equipment	ELH			0.117

Components Containing This Task: _____,

DISCUSSION

The task statement outline, Appendix B, is not all inclusive. For some of the components (ie. pumps), the tasks listed are comprehensive and include almost all actions that would be necessary during the life of a component. However, for other components (ie. some of the sludge handling equipment) there is very little information available and many components have become prematurely obsolete due to changes in operating factors such as energy costs. There are some components where the only tasks listed are preventive maintenance, repairs, and replacement as no more detailed task statements could be determined. The list of tasks provided is as comprehensive as possible based on the information that is currently available.

Veteran mechanics or electricians may feel that the labor hour estimates do not provide enough time to perform the task. The estimates may seem low because they are average craft times and do not include time to get to the job site, go for parts or materials, and trouble shoot. Actual times to perform the tasks can vary dramatically depending on the conditions the craftsman is confronted with. As an example, a bearing may be removed quickly if it is just starting to go bad, but it may have to be torched out if it

has seized to the shaft. Obviously, the necessary time to perform the task will be quite different in each case, but neither will be the same as the standard. The advantage of having standards is that they will provide an indication that further investigation is necessary. In some cases, the individuals may not be performing tasks as quickly as they should and more supervision or training may be necessary. In other cases, it may be a maintenance system that allows bearings to freeze to shafts that needs improvement. By using a system of standards, a good manager should be able to easily identify problems and thereby correct them sooner.

The EPS manuals that were used to determine labor hours for most of the task statements provide labor hour estimates with too many significant figures. Most tasks should be estimated to the nearest minute or five minutes and not to the nearest 0.36 second as is done in the manuals. The data input to the computer have been rounded off to the nearest 0.001 hour, but it is recognized that in actual practice standards probably will be written to the nearest 0.1 hour.

The frequencies that have been determined are average times for the particular task statement. Frequencies are very difficult to estimate because there are so many factors that have an effect on the values. The

major factor influencing frequencies is the presence or lack of standby units. If there are standby units and the "on" unit is rotated periodically, then repair and replacement frequencies will be much different from normal. Other major influences on frequency of task accomplishment are exposure to weather, quality of craftmen, quality of preventive maintenance, and suitability of the equipment for the application. The computer data base used has a provision for developing high and low factors that can be applied to the average frequency values, but this adjustment was not accomplished during this project because it would require a fairly substantial data sample to have meaningful results. There was very little information of this nature available at the time the study was conducted.

CONCLUSIONS

The purpose of this work was to develop a list of task statements that could be used by water and wastewater treatment plant managers to assist in setting maintenance budgets and determining staffing. A list of task statements has been presented and estimated labor hours and frequencies provided for many of the task statements. There is a serious need for an industry accepted set of standards for labor hours and frequencies. The numbers developed herein are a start, but much more work is necessary before they will be accepted as fact. The main impediment to this happening is not a lack of need, as most every computerized system requires that type of information in order to implement an effective maintenance system. What is needed, is a coordinated effort by one of the professional organizations in the field. It is recommended that a project similar to the Operations and Maintenance White Paper produced by the WPCF be conducted.[17] The methodolgy and results presented herein can be used to expand the data base and, ultimately, accomplish the goal initially established. It is anticipated that more information will be available within the next two to five years because there are many automated maintenance management systems

collecting the data today.

The Environmental Engineering profession must improve its public image. Much has been said in the technical literature and common press about how poorly treatment plants perform. The public is exposed to this poor record of performance almost daily and it is a black mark on our profession. This paper is an attempt to cause engineers to recognize that operations and maintenance play an important role in the performance of a treatment plant and that much work must be done to improve the management of operations and maintenance. It is the responsibility of all involved in the profession to take that extra step necessary to ensure that treatment plants perform as designed. It is very important that the public believe in the integrity and competence of the professionals in the field.

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APPENDICES

Appendix A

List of Components

APPENDIX A
LIST OF COMPONENTS

1616000 WATER TREATMENT PLANT

1616100 Pumping

- 1616110 Centrifugal Pump
- 1616120 Piping
- 1616130 Valves
- 1616140 Pump Motor

1616200 Rapid Mixer

- 1616210 Chamber
- 1616220 Mixing Tank
- 1616230 Mixer

1616300 Flocculation

- 1616310 Basin
- 1616320 Flocculator
- 1616330 Flocculator Motor

1616400 Clarification

- 1616410 Basin
- 1616420 Sludge Collector Mechanism
- 1616430 Sludge Collector Drive
- 1616440 Sludge Collector Drive Motor

1616500 Filtration, Ion Exchange, Activated Carbon

- 1616510 Concrete Basin
- 1616520 Steel Tank
- 1616530 Underdrain piping
- 1616540 Rate Control Valve
- 1616550 Backwash Pumps
- 1616560 Surface Wash System
- 1616570 Pump Motor

1616600 Chlorination and Flouridation

- 1616610 Chlorine Injectors
- 1616620 Chlorinator
- 1616630 Pressure Reducing Valve
- 1616640 Automatic Controls
- 1616650 Injector Booster Pump

1616700 Sludge Pumping

- 1616710 Piping
- 1616720 Pump Motor
- 1616730 Adjustable Speed Drive
- 1616740 Centrifugal Pump

1616800 Chemical Feed System

- 1616810 Storage Bin and Cyclone
- 1616820 Vibrator
- 1616830 Screw Dry Chemical Feeder
- 1616840 Piping
- 1616850 Agitator/Mixer
- 1616860 Conveyor
- 1616870 Motor
- 1616880 Slaking Tank
- 1616890 Metering Pump

1624000 SEWAGE TREATMENT PLANT

1624100 Raw wastewater Pumping

- 1624110 Centrifugal Pump
- 1624120 Pneumatic Ejector
- 1624130 Piping
- 1624140 Sewage Pump Motor

1624200 Comminutation

- 1624210 Comminutor Motor
- 1624220 Gear Box
- 1624230 Cutting Bars and Screen
- 1624240 Channel

1624300 Screening

- 1624310 Bars
- 1624320 Rake Mechanism
- 1624330 Rake Mechanism Motor
- 1624340 Channel

1624400 Primary Settling

- 1624410 Basin
- 1624420 Sludge Collector Mechanism
- 1624430 Sludge Collector Drive
- 1624440 Scum Collector
- 1624450 Sludge Collector Drive Motor

1624600 Aeration Tank - Diffused Aeration

- 1624610 Basin
- 1624620 Air Distribution System
- 1624630 Air Blower
- 1624640 Blower Motor
- 1624650 Air Filter System

1624700 Aeration Tank - Mechanical Aerator

- 1624710 Aerator
- 1624720 Aerator Motor
- 1624730 Basin

1624800 Secondary Clarifier

- 1624810 Basin
- 1624820 Sludge Collector Mechanism
- 1624830 Sludge Collector Drive

1624840 Scum Collector
1624850 Sludge Collector Drive Motor

1624900- Chlorination

1624910 Basin
1624920 Chlorine Injectors
1624930 Chlorinator
1624940 Pressure Reducing Valve
1624950 Automatic Controls
1624960 Booster Pump

1624A00 Sludge Pumping

1624A10 Piping
1624A20 Pump Motor
1624A30 Adjustable Speed Drive
1624A40 Plunger Pump
1624A50 Centrifugal Pump
1624A60 Rotary Positive Displacement Pump
1624A70 Diaphragm Pump
1624A80 Grinder Pump

1624B00 Aerobic Sludge Digestion

1624B10 Basin
1624B20 Air Distribution System
1624B30 Air Compressor
1624640 Compressor Motor
1624B50 Mechanical Aerator
1624B60 Mechanical Aerator Motor

1624C00 Trickling Filter

1624C10 Retaining Structure
1624C20 Distributor
1624C30 Undrain System

1624D00 Rotating Biological Contactor (RBC)

- 1624D10 RBC Motor
- 1624D20 Belt Drive
- 1624D30 Gear Reducer
- 1624D40 Chain Drive
- 1624D50 Tank Enclosure
- 1624D60 Rotating Plastic Media

1624E00 Stabilization Lagoon

- 1624E10 Earthen Basin
- 1624E20 Concrete Basin
- 1624E30 Diffused Air Distribution System
- 1624E40 Air Compressor
- 1624E50 Compressor Motor
- 1624E60 Mechanical Aerator
- 1624E70 Aerator Motor

1624F00 Dosing Tank

- 1624F10 Tank
- 1624F20 Piping
- 1624F30 Counter

1624G00 Flow Metering

- 1624G10 V-Notch Weir
- 1624G20 Float and Cable
- 1624G30 Sending/Receiving Transmitters
- 1624G40 Totalizer
- 1624G50 Recorder/Indicator

1624H00 Automatic Sampling

- 1624H10 Tubing
- 1624H20 Sampler

1624100 Sand Filtration

- 1624110 Backwash Pump
- 1624120 Pump Motor
- 1624130 Automatic Valve Operator and Valve
- 1624140 Surface Wash System
- 1624150 Underdrain System

1624J00 Sludge Drying Bed

- 1624J10 Piping/Channels
- 1624J20 Basin
- 1624J30 Underdrain
- 1624J40 Sand

1624K00 Anaerobic Digestor

- 1624K10 Tank
- 1624K20 Tank Cover-Fixed
- 1624K30 Tank Cover-Floating
- 1624K40 Heat Exchanger
- 1624K50 Pressure and Vacuum Relief Valves
- 1624K60 Flame Arrestor
- 1624K70 Instrumentation
- 1624K80 Condensate Trap
- 1624K90 Recirculation Pump
- 1624KA0 Gas Compressor
- 1624KB0 Gas Meter

1624L00 Vacuum Filtration

- 1624L10 Sludge Vat
- 1624L20 Filter Drum
- 1624L30 Filter Cloth
- 1624L40 Agitator
- 1624L50 Vacuum Pump
- 1624L60 Filtrate Pump
- 1624L70 Vacuum Control Valve
- 1624L80 Sludge Cake Conveyor

1624L90 Motor
1624LA0 Variable Speed Drive

1624M00 Centrifuge
1624M10 Rotating Bowl
1624M20 Rotating Conveyor
1624M30 Variable Speed Drive
1624M40 Motor

1624N00 Filter Press
1624N10 Filter Cloth
1624N20 Filter Plates
1624N30 Frame
1624N40 Closing Gear
1624N50 Motor
1624N60 Sludge Pump
1624N70 Piping

1624P00 Belt Pressure Filter
1624P10 Belt
1624P20 Scraping Blade
1624P30 Drive Mechanism
1624P40 Drive Motor

Appendix B

TASK STATEMENT OUTLINE

APPENDIX B
TASKOUTLINE

1616000 WATER TREATMENT PLANT

1616100 Pumping

1616110 Centrifugal Pump

1616111 lubricate
1616112 replace coupling
1616113 replace seals and packing
1616114 replace v-belts
1616115 disassemble and inspect impeller
1616116 replace impeller
1616117 replace housing
1616118 replace bearings
1616119 overhaul

1616120 Piping

1616122 repair leaks
1616123 replace

1616130 Valves

1616131 repack
1616133 replace

1616140 Pump Motor

1616141 lubricate
1616142 replace/rewind
1616143 clean and adjust controls
1616144 replace controls

1616200 Rapid Mixer

1616210 Chamber

1616211 dewater and clean
1616212 repair leaks
1616213 repair orifice plate
1616214 replace orifice plate

1616220 Mixing Tank

1616221 dewater, clean and repair
1616222 dewater and clean

1616230 Mixer
- 1616231 lubricate
- 1616232 repair mixing blades
- 1616233 replace mixing blades
- 1616234 replace mixing motor
- 1616235 replace mixer

1616300 Flocculation
- 1616310 Basin
  - 1616311 dewater, clean and patch
  - 1616312 dewater, clean
- 1616320 Flocculator
  - 1616321 lubricate
  - 1616322 repair paddles
  - 1616323 replace paddles
  - 1616324 replace bearings
  - 1616325 replace v-belts
  - 1616326 repair variable speed drive
  - 1616327 replace variable speed drive lubricant
  - 1616328 replace
- 1616330 Flocculator Motor
  - 1616331 lubricate
  - 1616332 replace/ rewind
  - 1616333 clean and adjust controls
  - 1616334 replace controls
  - 1616335 replace brushes/bearings

1616400 Clarification
- 1616410 Basin
  - 1616411 dewater, clean, repair cracks & spalling
  - 1616412 repair baffles
  - 1616413 replace baffles
  - 1616414 dewater and clean

1616420 Sludge Collector Mechanism
- 1616421 lubricate chain, bearings
- 1616422 replace worn or broken flights
- 1616423 replace worn or broken chain link
- 1616424 replace bearings
- 1616425 overhaul

1616430 Sludge Collector Drive
- 1616431 replace oil
- 1616432 replace shear pin
- 1616433 paint
- 1616434 replace oil seals
- 1616435 overhaul
- 1616436 lubricate

1616440 Sludge Collector Drive Motor
- 1616441 lubricate bearings
- 1616442 replace/rewind motor

1616500 Filtration, Ion Exchange, Activated Carbon

1616510 Concrete Basin
- 1616511 dewater, clean and patch
- 1616512 dewater and clean

1616520 Steel Tank
- 1616521 clean and paint
- 1616522 repair leaks

1616530 Underdrain Piping
- 1616532 repair leaks
- 1616533 repack valves
- 1616534 replace valves
- 1616535 replace piping

1616540 Rate Control Valve
- 1616541 lubricate and adjust
- 1616542 calibrate control
- 1616543 repack stem
- 1616544 repair
- 1616545 replace

1616550 Backwash Pumps
- 1616551 lubricate
- 1616552 disassemble and inspect
- 1616553 replace impeller
- 1616554 replace coupling
- 1616555 replace shaft
- 1616556 repair housin
- 1616557 replace seals and packing
- 1616558 overhaul

1616560 Surface Wash System
- 1616561 repair piping
- 1616562 replace piping
- 1616563 repair nozzles
- 1616564 replace nozzles
- 1616565 repair controls
- 1616566 replace controls
- 1616567 replace

1616570 Pump Motor
- 1616571 lubricate
- 1616572 replace/rewind

1616600 Chlorination and Flouridation
- 1616610 Chlorine Injectors
  - 1616612 replace piping
  - 1516613 replace jets

1616620 Chlorinator
- 1616621 clean, inspect and calibrate
- 1616622 replace flexible tubing
- 1616623 repair leaks
- 1616624 replace

1616630 Pressure Reducing Valve
- 1616631 clean and adjust
- 1616632 replace diaphragm
- 1616633 replace

1616640 Automatic Controls
- 1616641 clean and calibrate
- 1616642 replace

1616650 Injector Booster Pump
- 1616651 lubricate
- 1616652 replace bearings and packing
- 1616653 replace sleeve
- 1616654 overhaul

1616700 Sludge Pumping

1616710 Piping
- 1616711 flush piping
- 1616712 disassemble and rod out
- 1616713 repair leaks
- 1616714 repack valves
- 1616715 replace valves
- 1616716 clean and paint

1616720 Pump Motor
- 1616721 lubricate
- 1616722 clean, adjust, and calibrate controls
- 1616723 replace controls
- 1616724 replace/rewind motor

1616730 Adjustable Speed Drive
- 1616731 lubricate
- 1616732 replace seals
- 1616733 replace lubricant
- 1616734 overhaul

1616740 Centrifugal Pump
- 1616741 lubricate
- 1616742 replace seals and packing
- 1616743 replace coupling
- 1616744 replace v-belts
- 1616745 disassemble and check impeller
- 1616746 replace impeller
- 1616747 replace bearings
- 1616748 overhaul

1616800 Chemical Feed System

1616810 Storage Bin and Cyclone
- 1616811 clean and paint
- 1616812 repair walls
- 1616813 replace

1616820 Vibrator
- 1616821 lubricate
- 1616822 replace bearings
- 1616823 repair vibrating plate
- 1616824 replace plate

1616830 Screw Dry Chemical Feeder
- 1616831 lubricate
- 1616832 replace belts
- 1616833 replace bearings
- 1616834 replace

1616840 Piping
- 1616841 clean and flush
- 1616842 repair
- 1616843 replace

1616850 Agitator/Mixer
- 1616851 lubricate
- 1616852 replace bearings
- 1616853 replace eccentric gear
- 1616854 repair framing
- 1616855 repair blade
- 1616856 replace blades
- 1616857 overhaul

1616860 Conveyor
- 1616861 lubricate
- 1616862 replace bearings
- 1616863 adjust and align belt
- 1616864 repair conveyor belt
- 1616865 replace conveyor belt
- 1616866 repair framing
- 1616867 overhaul

1616870 Motor
- 1616871 lubricate
- 1616872 replace/rewind

1616880 Slaking Tank
- 1616881 clean and paint
- 1616882 repair walls and bottom
- 1616883 repair baffle
- 1616884 replace

1616890 Metering Pump
- 1616891 preventive maintenance
- 1616893 repair
- 1616894 replace

1624000 SEWAGE TREATMENT PLANT

1624100 Raw wastewater Pumping

1624110 Centrifugal Pump

1624111 lubricate bearings
1624113 replace packing/seals
1624114 replace coupling
1624115 replace v-belts
1624116 disassemble and inspect
1624117 replace impeller
1624118 replace bearings
1624119 overhaul

1624120 Pneumatic Ejector

1624121 lubricate pilot valve and linkage
1624122 clean compressor air strainer
1624123 PM air compressor
1624124 overhaul air compressor
1624125 clean and paint
1624126 overhaul

1624130 Piping

1624131 flush
1624132 repair leaks
1624133 repack valve
1624134 replace valve
1624135 replace check valve
1624136 PM on check valve

1624140 Sewage Pump Motor

1624141 lubricate bearings
1624142 replace/rewind
1624143 clean and adjust controls
1624144 replace controls

1624200 Comminutation

1624210 Comminutor Motor

1624211 lubricate bearings
1624212 replace/rewind motor

1624220 Gear Box
- 1624221 lubricate
- 1624222 change lubricant
- 1624223 replace gears
- 1624224 replace coupler
- 1624225 replace oil seals
- 1624226 clean and paint housing

1624230 Cutting Bars and Screen
- 1624231 inspect and adjust cutters
- 1624232 sharpen cutting bars
- 1624233 replace worn cutting bars
- 1624234 unclog jammed mechanism

1624240 Channel
- 1624241 clean, repair cracks & spalling
- 1624242 replace corroded gates
- 1624243 clean and flush channel

1624300 Screening.

1624310 Bars
- 1624311 repair broken/corroded bar
- 1624312 replace bars

1624320 Rake Mechanism
- 1624321 lubricate bearings and chain
- 1624322 replace bearings
- 1624323 replace worn/broken chain links
- 1624324 replace worn/broken rake tines
- 1624325 repair worn/broken screen
- 1624326 overhaul

1624330 Rake Mechanism Motor
- 1624331 clean and adjust controls
- 1624332 lubricate bearings
- 1624333 replace/rewind motor
- 1624334 replace controls

1624340 Channel
- 1624341 clean, repair cracks & spalling

1624342 replace corroded gates
1624343 clean and flush channel

1624400 Primary Settling
1624410 Basin
1624411 dewater, clean, repair cracks & spalling
1624412 dewater and clean
1624420 Sludge Collector Mechanism
1624421 lubricate chain, bearings
1624422 replace worn or broken flights
1624423 replace worn or broken chain link
1624424 replace bearings
1624425 replace worn/broken chain and sprockets
1624426 overhaul
1624430 Sludge Collector Drive
1624431 replace oil
1624432 lubricate
1624433 paint
1624434 replace oil seals
1624435 replace shear pin
1624436 overhaul
1624440 Scum Collector
1624441 replace worn or broken flights
1624442 replace corroded hopper
1624443 unplug hopper
1624444 replace
1624450 Sludge Collector Drive Motor
1624451 lubricate bearings
1624452 replace/rewind motor

1624600 Aeration Tank - Diffused Aeration
1624610 Basin
1624611 dewater, clean, repair cracks & spalling
1624612 dewater and clean
1624620 Air Distribution System

1624621 remove from tank, inspect and clean
1624622 repair leaks
1624630 Air Blower
1624631 clean and check pressure relief valve
1624632 lubricate bearings
1624633 replace belts
1624634 paint
1624635 overhaul
1624636 drain, flush, refill oil resevoir
1624640 Blower Motor
1624641 lubricate bearings
1624642 replace/rewind
1624650 Air Filter System
1624651 clean/replace air filter elements

1624700 Aeration Tank - Mechanical Aerator
1624710 Aerator
1624711 lubricate
1624712 repair/replace impellers
1624713 replace bearings
1624714 replace coupling
1624720 Aerator Motor
1624721 lubricate bearings
1624722 replace/rewind motor
1624730 Basin
1624731 dewater, clean, repair cracks & spalling
1624732 dewater and clean

1624800 Secondary Clarifier
1624810 Basin
1624811 dewater, clean, repair cracks & spalling
1624812 dewater and clean
1624820 Sludge Collector Mechanism
1624821 lubricate chain, bearings
1624822 replace worn or broken flights

1624823 replace worn or broken chain link
1624824 replace bearings
1624825 replace worn/broken chain and sprockets
1624826 overhaul

1624830 Sludge Collector Drive
1624831 replace lubricant
1624832 lubricate
1624833 paint
1624834 replace oil seals
1624835 replace shear pin
1624836 overhaul

1624840 Scum Collector
1624841 replace worn or broken flights
1624842 replace corroded hopper
1624843 unplug hopper
1624844 replace

1624850 Sludge Collector Drive Motor
1624851 lubricate bearings
1624852 replace/rewind motor

1624900- Chlorination

1624910 Basin
1624911 dewater, clean and repair
1624912 dewater and clean

1624920 Chlorine Injectors
1624921 disassemble and clean
1624922 replace piping
1624923 replace jets
1624924 overhaul

1624930 Chlorinator
1624931 clean, inspect and calibrate
1624932 replace flexible tubing
1624933 repair leaks
1624934 replace

1624940 Pressure Reducing Valve
- 1624941 clean and adjust
- 1624942 replace diaphragm
- 1624943 replace

1624950 Automatic Controls
- 1624951 clean and calibrate
- 1624952 replace

1624960 Booster Pump
- 1624961 lubricate
- 1624962 replace bearings and packing
- 1624963 replace sleeve
- 1624964 overhaul

1624A00 Sludge Pumping

1624A10 Piping
- 1624A11 flush piping
- 1624A12 disassemble and rod out
- 1624A13 repair leaks
- 1624A14 repack valves
- 1624A15 replace valves
- 1624A16 clean and paint

1624A20 Pump Motor
- 1624A21 lubricate
- 1624A22 clean, adjust, and calibrate controls
- 1624A23 replace controls
- 1624A24 replace/rewind motor

1624A30 Adjustable Speed Drive
- 1624A31 lubricate
- 1624A32 replace seals
- 1624A33 replace lubricant
- 1624A34 overhaul

1624A40 Plunger Pump
- 1624A41 lubricate
- 1624A42 replace packing
- 1624A43 replace coupling

1624A44 replace check valve
1624A45 replace piston rings
1624A46 replace v-belts
1624A47 overhaul
1624A50 Centrifugal Pump
1624A51 lubricate
1624A52 replace seals and packing
1624A53 replace coupling
1624A54 replace v-belts
1624A55 disassemble and check impeller
1624A56 replace impeller
1624A57 replace bearings
1624A58 overhaul
1624A60 Rotary Positive Displacement Pump
1624A61 lubricate
1624A62 disassemble and check rotor clearance
1624A63 replace rotor
1624A64 replace coupling
1624A65 replace bearings
1624A66 replace v-belts
1624A67 overhaul
1624A70 Diaphragm Pump
1624A71 lubricate
1624A72 disassemble and clean check valve
1624A73 replace check valve
1624A74 replace diaphragm
1624A75 replace compressor air filters
1624A76 repair air compressor
1624A77 overhaul air compressor
1624A78 overhaul pump
1624A79 preventive maintenance on air compressor
1624A80 Grinder Pump
1624A81 lubricate
1624A82 resurface cutters
1624A83 replace cutters

1624A84 replace seals and packing
1624A85 replace bearings
1624A86 overhaul pump

1624B00 Aerobic Sludge Digestion
1624B10 Basin
1624B11 dewater, clean and repair
1624B12 dewater and clean
1624B20 Air Distribution System
1624B21 disassemble and unclog
1624B22 repair leaks
1624B23 replace nozzles
1624B24 replace piping
1624B30 Air Compressor
1624B31 lubricate
1624B32 clean and check pressure relief valve
1624B33 replace belts
1624B34 paint
1624B35 overhaul
1624B36 drain, flush, refill oil
1624640 Compressor Motor
1624B41 lubricate bearings
1624B42 replace/rewind
1624B50 Mechanical Aerator
1624B51 lubricate
1624B52 repair/replace impellers
1624B53 replace bearings
1624B54 replace coupling
1624B60 Mechanical Aerator Motor
1624B61 lubricate bearings
1624B62 replace/rewind motor

1624C00 Trickling Filter
1624C10 Retaining Structure
1624C11 clean and patch structure

1624C12 repair leaks
1624C20 Distributor
1624C21 lubricate
1624C22 replace lubricant and adjust guy rods
1624C23 flush nozzles and laterals
1624C24 replace nozzles
1624C25 replace bearings and seals
1624C26 overhaul
1624C30 Undrain System
1624C31 flush clean

1624D00 Rotating Biological Contactor (RBC)
1624D10 RBC Motor
1624D11 lubricate
1624D12 replace/ rewind
1624D20 Belt Drive
1624D21 lubricate
1624D22 replace belts
1624D23 replace sheaves
1624D30 Gear Reducer
1624D31 lubricate
1624D32 replace seals
1624D33 replace lubricant
1624D34 overhaul
1624D40 Chain Drive
1624D41 lubricate
1624D42 replace lubricant
1624D43 replace chain and sprockets
1624D44 replace chain link
1624D46 overhaul
1624D50 Tank Enclosure
1624D51 repair leaks
1624D52 dewater and clean
1624D53 paint

1624D60 Rotating Plastic Media
- 1624D61 lubricate bearings
- 1624D62 replace bearings
- 1624D63 repair shaft
- 1624D64 replace shaft

1624E00 Stabilization Lagoon
- 1624E10 Earthen Basin
  - 1624E11 repair basin walls
  - 1624E12 dewater and remove solids
- 1624E20 Concrete Basin
  - 1624E21 repair basin walls
  - 1624E22 dewater and remove solids
- 1624E30 Diffused Air Distribution System
  - 1624E31 remove from tank, inspect and clean
  - 1624E32 repair leaks
- 1624E40 Air Compressor
  - 1624E41 clean and check pressure relief valve
  - 1624E42 lubricate bearings
  - 1624E43 replace belts
  - 1624E44 paint
  - 1624E45 overhaul
  - 1624E46 change lubricant
- 1624E50 Compressor Motor
  - 1624E51 lubricate bearings
  - 1624E52 replace/rewind motor
- 1624E60 Mechanical Aerator
  - 1624E61 lubricate
  - 1624E62 repair/replace impellers
  - 1624E63 replace bearings
  - 1624E64 replace coupling
- 1624E70 Aerator Motor
  - 1624E71 lubricate bearings
  - 1624E72 replace/rewind motor

1624F00 Dosing Tank
- 1624F10 Tank
  - 1624F11 drain and clean
  - 1624F12 repair leaks
- 1624F20 Piping
  - 1624F21 flush
  - 1624F22 repair leaks
  - 1624F23 repack valve
  - 1624F24 replace valve
  - 1624F25 replace protective coating on piping and valves
  - 1624F26 overhaul
- 1624F30 Counter
  - 1624F31 clean, oil and adjust
  - 1624F32 replace

1624G00 Flow Metering
- 1624G10 V-Notch Weir
  - 1624G11 clean and level
  - 1624G12 replace
- 1624G20 Float and Cable
  - 1624G21 clean, oil, adjust, and calibrate
  - 1624G22 replace
- 1624G30 Sending/Receiving Transmitters
  - 1624G31 calibrate
  - 1624G32 replace
- 1624G40 Totalizer
  - 1624G41 calibrate
  - 1624G42 replace
- 1624G50 Recorder/Indicator
  - 1624G51 calibrate
  - 1624G52 replace pen and ink
  - 1624G53 replace

1624H00 Automatic Sampling

- 1624H10 Tubing
  - 1624H11 disassemble and flush
  - 1624H12 replace
- 1624H20 Sampler
  - 1624H21 PM by factory representative
  - 1624H22 repairs
  - 1624H23 replace

1624I00 Sand Filtration

- 1624I10 Backwash Pump
  - 1624I11 lubricate bearings
  - 1624I13 replace packing and seals
  - 1624I14 replace coupling
  - 1624I15 replace v-belts
  - 1624I16 disassemble and check impeller
  - 1624I17 replace impeller
  - 1624I18 replace bearings
  - 1624I19 overhaul
- 1624I20 Pump Motor
  - 1624I21 lubricate
  - 1624I22 replace/rewind
- 1624I30 Automatic Valve Operator and Valve
  - 1624I32 replace packing
  - 1624I33 rebuild operator
  - 1624I34 replace valve
- 1624I40 Surface Wash System
  - 1624I41 unclog orifices
  - 1624I42 replace orifices
  - 1624I43 repair leaking piping
- 1624I50 Underdrain System
  - 1624I52 replace

1624J00 Sludge Drying Bed
- 1624J10 Piping/Channels
  - 1624J11 flush
  - 1624J12 repair
  - 1624J13 replace
- 1624J20 Basin
  - 1624J21 clean
  - 1624J22 repair
- 1624J30 Underdrain
  - 1624J31 flush
  - 1624J32 repair
  - 1624J33 replace
- 1624J40 Sand
  - 1624J41 till and relevel
  - 1624J42 replace

1624K00 Anaerobic Digestor
- 1624K10 Tank
  - 1624K11 empty and clean
  - 1624K12 repair walls
- 1624K20 Tank Cover-Fixed
  - 1624K21 clean and inspect
  - 1624K22 repair and patch
- 1624K30 Tank Cover-Floating
  - 1624K31 clean and inspect
  - 1624K32 repair and patch
  - 1624K33 renew side skirts
  - 1624K34 replace
- 1624K40 Heat Exchanger
  - 1624K41 clean tubes
  - 1624K42 repair tubes
  - 1624K43 replace tube bundle
  - 1624K44 repair piping
  - 1624K45 replace piping
  - 1624K46 flush piping

1624K47 clean and calibrate temperature controls
1624K49 replace temperature control
1624K4A perform hydrostatic test and certification
1624K50 Pressure and Vacuum Relief Valves
1624K51 clean and check operation
1624K52 replace
1624K60 Flame Arrestor
1624K61 clean and inspect
1624K62 replace
1624K70 Instrumentation
1624K71 clean and calibrate
1624K72 repair
1624K73 replace
1624K80 Condensate Trap
1624K81 clean and inspect
1624K82 repair
1624K83 replace
1624K90 Recirculation Pump
1624K91 lubricate
1624K92 replace impeller
1624K93 replace motor
1624K94 replace pump
1624KA0 Gas Compressor
1624KA1 preventive maintenance, inspection, alignment
1624KA2 repair
1624KA3 replace
1624KB0 Gas Meter
1624KB1 preventative maintenance
1624KB2 repair
1624KB3 replace

1624L00 Vacuum Filtration

- 1624L10 Sludge Vat
  - 1624L11 dewater, clean and inspect
  - 1624L12 repair
  - 1624L13 overhaul
- 1624L20 Filter Drum
  - 1624L21 preventive maintenance
  - 1624L22 repair drum
  - 1624L23 replace drum
  - 1624L24 lubricate shaft bearings
  - 1624L25 replace bearings
  - 1624L26 repair shaft
  - 1624L27 replace shaft
- 1624L30 Filter Cloth
  - 1624L31 repair cloth
  - 1624L32 replace
- 1624L40 Agitator
  - 1624L41 preventive maintenace
  - 1624L42 repair
  - 1624L43 replace
- 1624L50 Vacuum Pump
  - 1624L51 lubricate
  - 1624L52 repair
  - 1624L53 replace
- 1624L60 Filtrate Pump
  - 1624L61 lubricate
  - 1624L62 replace seals/packing
  - 1624L63 replace coupling
  - 1624L64 replace v-belts
  - 1624L65 disassemble and check impeller
  - 1624L66 replace impeller
  - 1624L67 replace bearings
  - 1624L68 overhaul

1624L70 Vacuum Control Valve
- 1624L71 disassemble,clean and adjust
- 1624L72 repair
- 1624L73 replace

1624L80 Sludge Cake Conveyor
- 1624L81 lubricate
- 1624L82 replace bearings
- 1624L83 adjust and align belt
- 1624L84 repair conveyor belt
- 1624L85 replace conveyor belt
- 1624L85 repair framing

1624L90 Motor
- 1624L91 lubricate
- 1624L92 replace/rewind

1624LA0 Variable Speed Drive
- 1624LA1 lubricate
- 1624LA2 replace lubricant
- 1624LA3 replace seals
- 1624LA4 overhaul

1624M00 Centrifuge

1624M10 Rotating Bowl
- 1624M11 lubricate
- 1624M12 replace bearings
- 1624M13 repair bowl walls
- 1624M14 overhaul

1624M20 Rotating Conveyor
- 1624M21 preventive maintenance
- 1624M22 repair
- 1624M23 overhaul

1624M30 Variable Speed Drive
- 1624M31 lubricate
- 1624M32 replace lubricant
- 1624M33 replace seals

1624M34 overhaul
1624M40 Motor
1624M41 lubricate
1624M42 replace/rewind

1624N00 Filter Press
1624N10 Filter Cloth
1624N11 repair cloth
1624N12 replace
1624N20 Filter Plates
1624N21 preventive maintenance
1624N22 repair
1624N23 replace
1624N30 Frame
1624N31 clean and paint
1624N32 repair
1624N33 replace
1624N40 Closing Gear
1624N41 lubricate
1624N42 repair
1624N43 replace gear
1624N44 overhaul
1624N50 Motor
1624N51 lubricate
1624N52 replace/rewind
1624N60 Sludge Pump
1624N61 lubricate
1624N62 disassemble and inspect
1624N63 replace impeller
1624N64 replace motor
1624N65 replace coupling
1624N66 overhaul
1624N67 replace seals/packing

1624N70 Piping
- 1624N71 flush
- 1624N72 repair leaks
- 1624N73 replace
- 1624N74 repack valves
- 1624N75 replace valves

1624P00 Belt Pressure Filter
- 1624P10 Belt
  - 1624P11 repair belt
  - 1624P12 replace belt
  - 1624P13 lubricate drum bearings
  - 1624P14 replace drum bearings
  - 1624P15 adjust belt alignment
  - 1624P16 repair drum
  - 1624P17 replace drum
  - 1624P18 overhaul
- 1624P20 Scraping Blade
  - 1624P21 clean and adjust
  - 1624P22 resurface edge
  - 1624P23 replace
- 1624P30 Drive Mechanism
  - 1624P31 lubricate
  - 1624P32 replace lubricant
  - 1624P33 replace seals
  - 1624P34 overhaul
- 1624P40 Drive Motor
  - 1624P41 lubricate
  - 1624P42 replace/rewind motor

Appendix C

INSTRUCTIONS FOR DATA BASE ACCESS

INSTRUCTIONS FOR DATA BASE ACCESS

It is necessary for a potential user of the data base program used here to be thoroughly familiar with the operating system of the computer and be able to load and access D-Base III. Those instructions are beyond the scope of this paper and are better learned from the manuals that accompany the programs.

1. Load D-Base III. From the dot prompt (.) type "DO RN-MAIN". A screen will appear that asks for today's date (Figure C-1). Type in the date using the format month/day/year and hit the return key.

2. The next screen (Figure C-2) will give you four choices for functions to perform and ask you to hit the appropriate number key. If you hit a key that is not a choice, the screen will reappear. A "0" will bring you back to the D-Base dot prompt.

3. If you want to add records, then you hit the "1" key. This action will cause the next screen to appear (Figure C-3). This screen gives you the option of adding records to the area file (1), the system file (2), the subsystem file (3), the task data file (4), or return to the main menu (0) by hitting the appropriate number key. The first three files were created for use by CERL and probably are not of interest. To add input to the task data file, hit the number "4" and the return key.

   a. The next screen (Figure C-4) will ask you if you want to input data

(D), edit (E), or quit (Q). If you hit an "E", the program will put you into the edit mode (see that paragraph for details). If you hit the "Q", the program will bring you back to the previous screen. If you hit the "D", then it will continue in the add mode. Any other key will give you the screen back again.

b. Once you hit the "D" key, the program will ask you for the task code number (Figure C-5). Type in the seven digit number for the task code. The computer will use the first six digits to identify the component and ask you if it is correct (Figure C-6). If you type a "T" for yes it will proceed to the next menu (Figure C-7). If you type an "F" for no, it will go back to the previous menu.

c. If the computer does not find the component in the component file, it will generate a new screen (Figure C-8) that will ask you if you want to add ("A") to the component file, try ("T") another number or quit ("Q") to the main menu. Try will let you try another number and quit will bring you back to the main menu. Add will generate a new screen (Figure C-9) that asks you for the name of the component. When you type it in and hit the return key, the computer will go on with the next screen in the add mode (Figure C-7).

d. The screen shown in Figure C-7 asks you to input data to the task description code field, description of task field and unit of measure field. The task description code field is a code used to identify the task as preventive maintenance (PM), repairs (M/R), or replacement (REPLACE)

action. The appropriate code should be entered. The description of task entry is self explanatory. The unit of measure field is limited to the following entries: one each (1-CT), per linear foot (1-LF), per square foot (1-SF), and per 1000 linear feet (3-LF).

e. After this information is entered, the next screen appears (Figure C-10). This screen repeats the task description entered previously and has a memo field. The memo field is represented by the word "memo" and is used to document how the estimates were arrived at. To enter the memo field, put the cursor over the word "memo" and hit the control-page down keys in combination. This action will bring up a blank page on which information can be entered, similar to that used in a word processor. When you are finished with the memo field, hit the combination of control - page up keys. Next, hit the page down key to generate the final screen in the add mode (Figure C-11).

f. Entry of information into this screen is self explanatory. It should be noted that much of the information only is entered for the purposes of the CERL project and can be omitted if not necessary for your purposes. Upon completion of this screen, the program will give you the chance to add another record or go back to the main menu.

4. The edit mode allows you to review and revise each record to correct errors and update information. It uses many of the same screens as the add mode, only there is information already entered in each of the fields. For example, in the task data information file edit will call up the screens shown in Figures C-7, C-10, and C-11. To edit a file, start from

the main menu (Figure C-2) and hit the "2" key. The screen that will be generated (Figure C-12) will ask you which file you wish to use: the system, sub-system, component, or task data information files. Whichever of the files you decide to enter, the next screen will ask you to enter the appropriate number of the record you want. For example, for the task data information file the program needs the seven digit task code number and for the component file the program needs the six digit component number. Refer to Appendices A and B if you do not have the appropriate number.

To revise information in a record, position the cursor over the incorrect information and type over it. The new information is not saved to the disk until the next screen is generated. Until that point you can revise as often as you wish without actually changing the record. But once you go to the next screen, it is necessary to leave the record and re-enter it if you decide the revision was incorrect.

5. Reports can be generated by returning to the main menu (Figure C-2) and hitting the "3" key. This action will call up a menu screen (Figure C-13) for the two types of reports available: basic task information table or a task data form. The format for both of the reports was dictated by CERL for its purposes and requires a 15 inch wide platen printer. It is possible that a program such as "Sidewinder" ,that turns a printed page sideways, could be used since the document produced while 14 inches wide is only 8.5 inches long. Use of such a program was not investigated.

a. The basic task information table provides columns of a few fields from the task data file for all task codes called. It can be obtained by hitting the "1" key of the screen shown in Figure C-13 which in turn will generate a new screen (Figure C-14). In this screen, the program asks you to select which report you want. Note that flooring is one of the other sections of the CERL project and selection of that choice will not generate any report as that particular file is empty. A sample of the basic information table is shown in Figure C-15.

b. The task data form provides an individual sheet for each task code number. The form is designed to provide the reader with all the pertinent information about any task statement. A sample is provided as Figure C-16. There will be one or two more screens after that shown in Figure C-13 that give you the opportunity to tailor the content of the report depending on your needs. You can get a report with sheets for only one task record, one with all, or one with a portion of the file.

6. File maintenance is an important function that is provided from the main menu. It allows you to back up your files onto floppy disks which can be put in a safe place. If anything were to happen to the hard disk in the computer, your backup copies could be used to replace those files lost. Backup has been done weekly for the CERL project.

a. Select the file maintenance mode by hitting the "4" key in the main menu. This action will generate a new screen (Figure C-17) which asks you if you wish to make backup copies of your files or re-index data

files. The re-index selection does not work and should not be selected. Re-indexing can be done directly from the dot prompt in D-Base.

b. Selection of the backup files option will generate a new screen (Figure C-18) that asks you which file you wish to backup. Note that the task data file has been divided in half because it will not all fit on one floppy disk. Follow the directions to obtain your backup floppy disk. It takes approximately ten minutes for the task data files to be copied.

FIGURE C-1

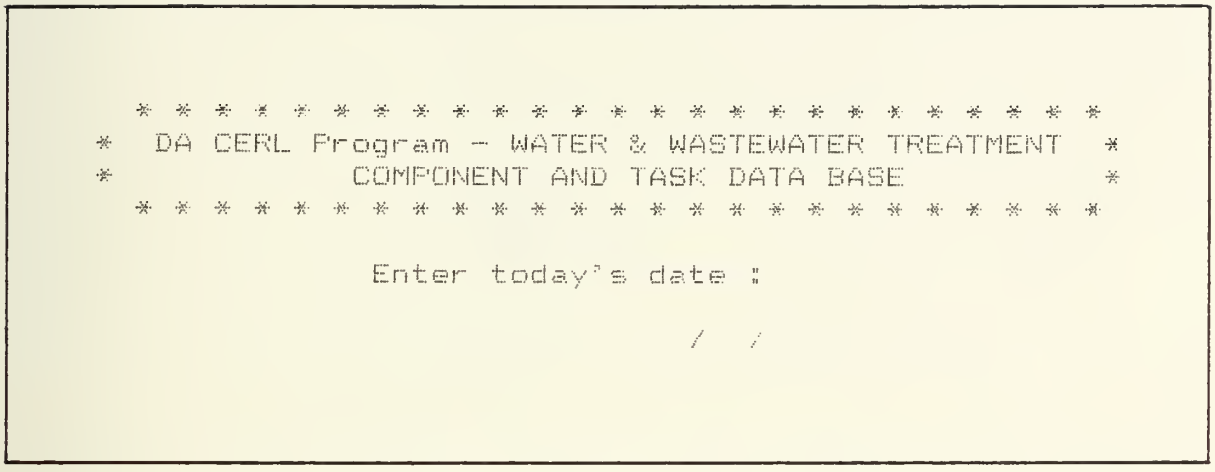


FIGURE C-2

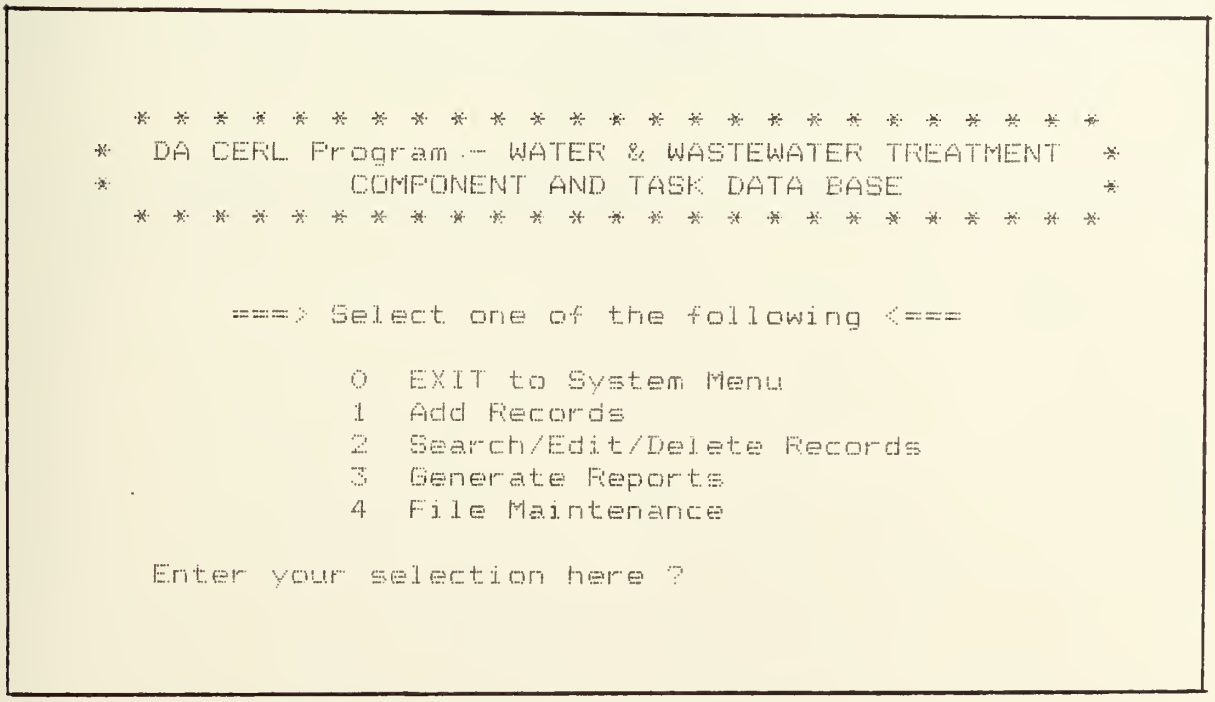


FIGURE C-3

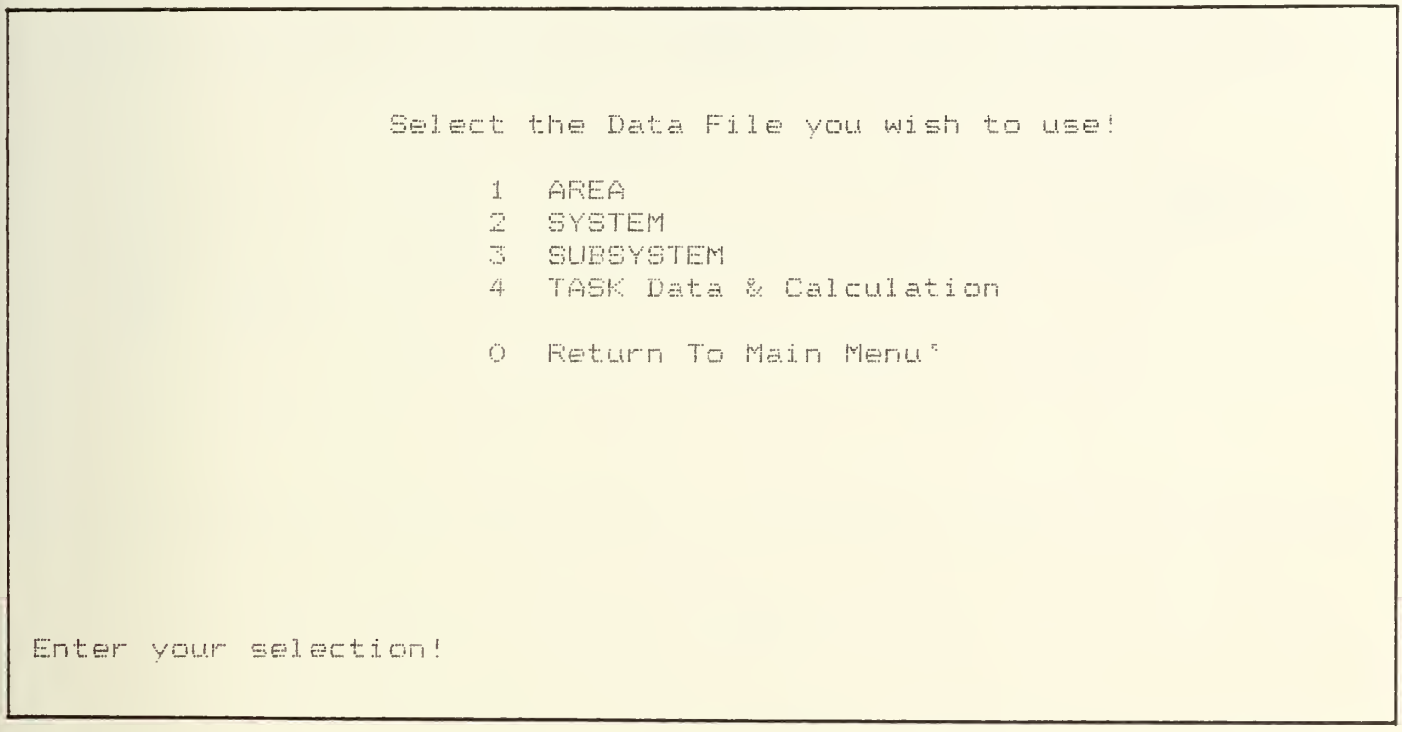


FIGURE C-4

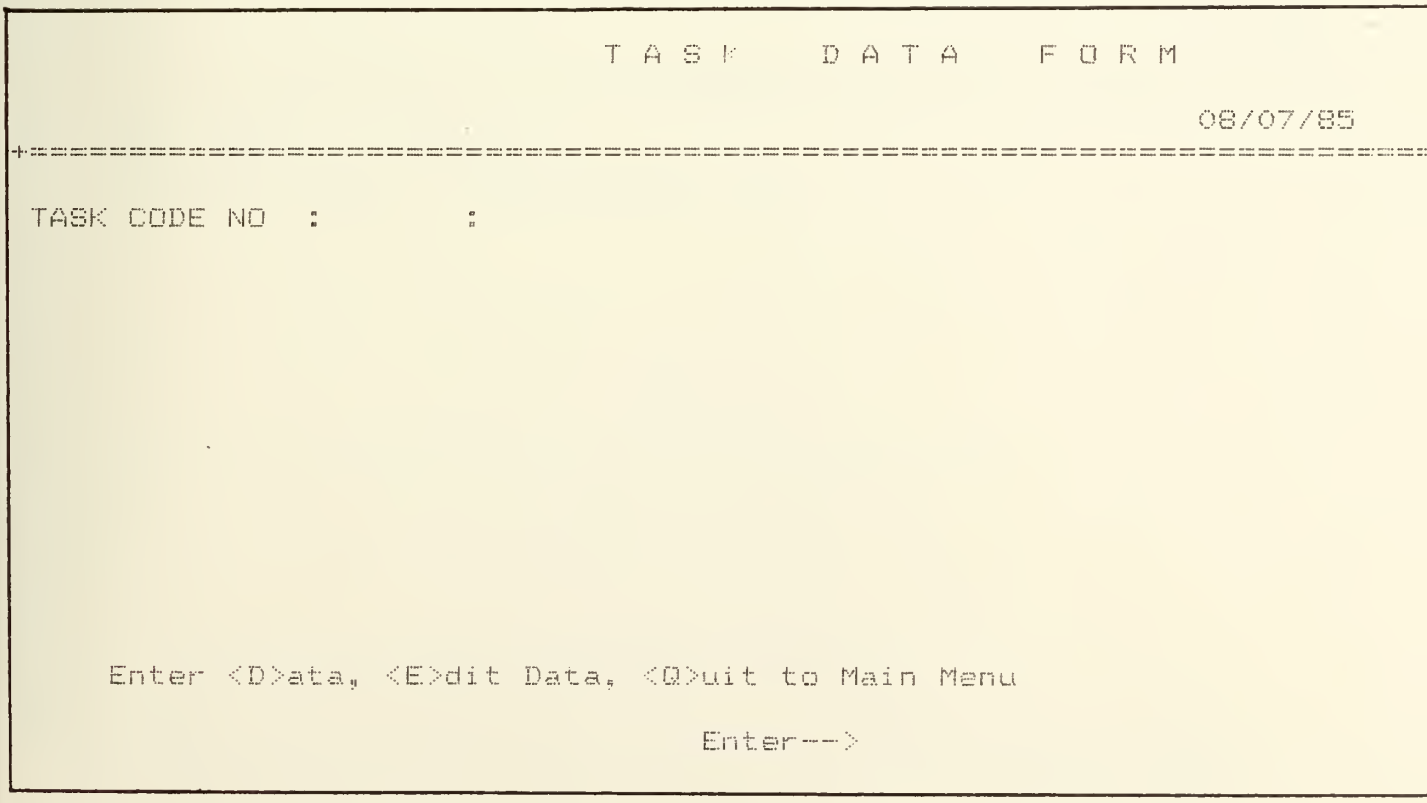


FIGURE C-5

```
                    T A S K    D A T A    F O R M

                                                          08/07/85
+=========================================================================+

 TASK CODE NO  :        :
```

FIGURE C-6

```
                    T A S K    D A T A    F O R M

                                                          08/07/85
+=========================================================================+

 TASK CODE NO  :161611Y:
 Component Descr   :CENTRIFUGAL PUMP:




     Is this the right component (T/F)? T
```

FIGURE C-7

```
Enter the following information:

Task Description Code
Description of Task
Unit of Measure
```

FIGURE C-8

```
                    T A S K   D A T A   F O R M

                                                          08/07/85
+=============================================================================+

TASK CODE NO  :8888888:




Component not found.  Enter <A>dd to Component
Data File, <T>ry another number, or <Q>uit to Main Menu.
```

FIGURE C-9

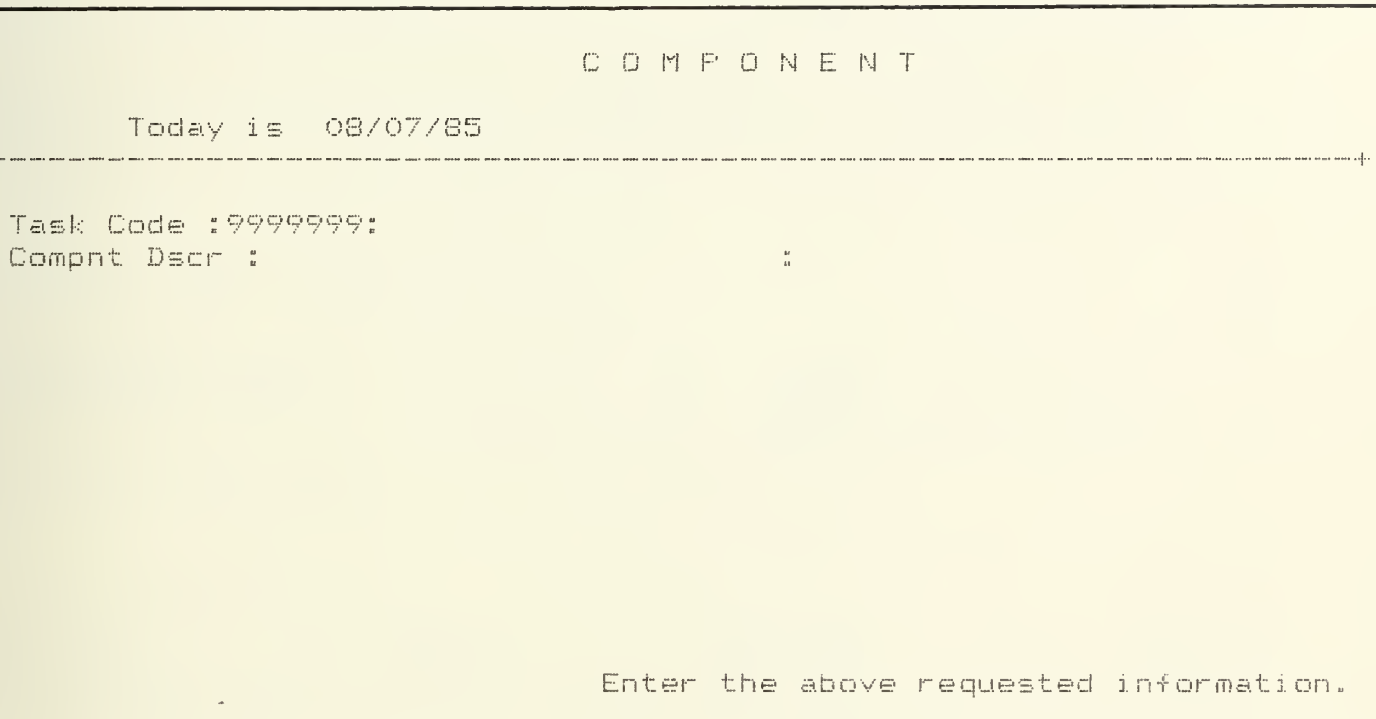


FIGURE C-10

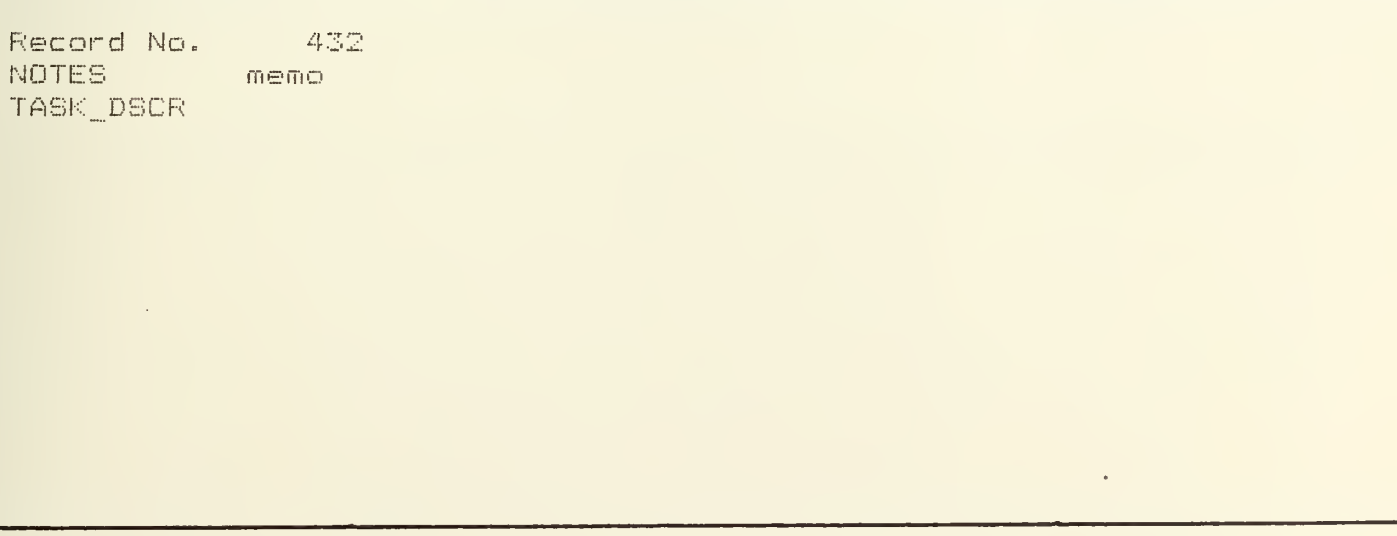


FIGURE C-11

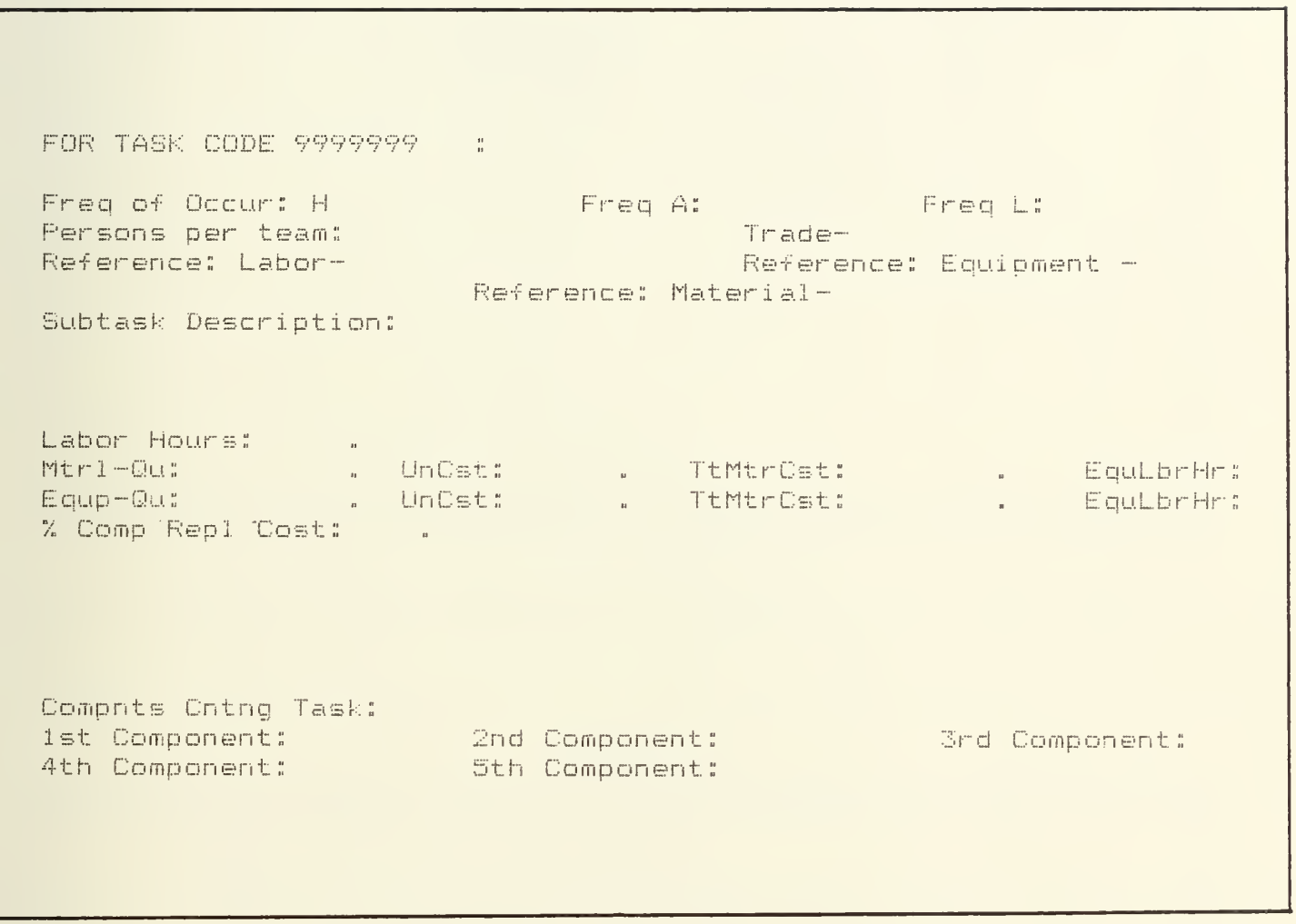

FOR TASK CODE 9999999 :
Freq of Occur: H
Freq A:
Freq L:
Persons per team:
Trade-
Reference: Labor-
Reference: Equipment -
Reference: Material-
Subtask Description:
Labor Hours: .
Mtrl-Qu: . UnCst: . TtMtrCst: . EquLbrHr:
Equp-Qu: . UnCst: . TtMtrCst: . EquLbrHr:
% Comp Repl Cost: .
Comprnts Cntng Task:
1st Component:
2nd Component:
3rd Component:
4th Component:
5th Component:

FIGURE C-12

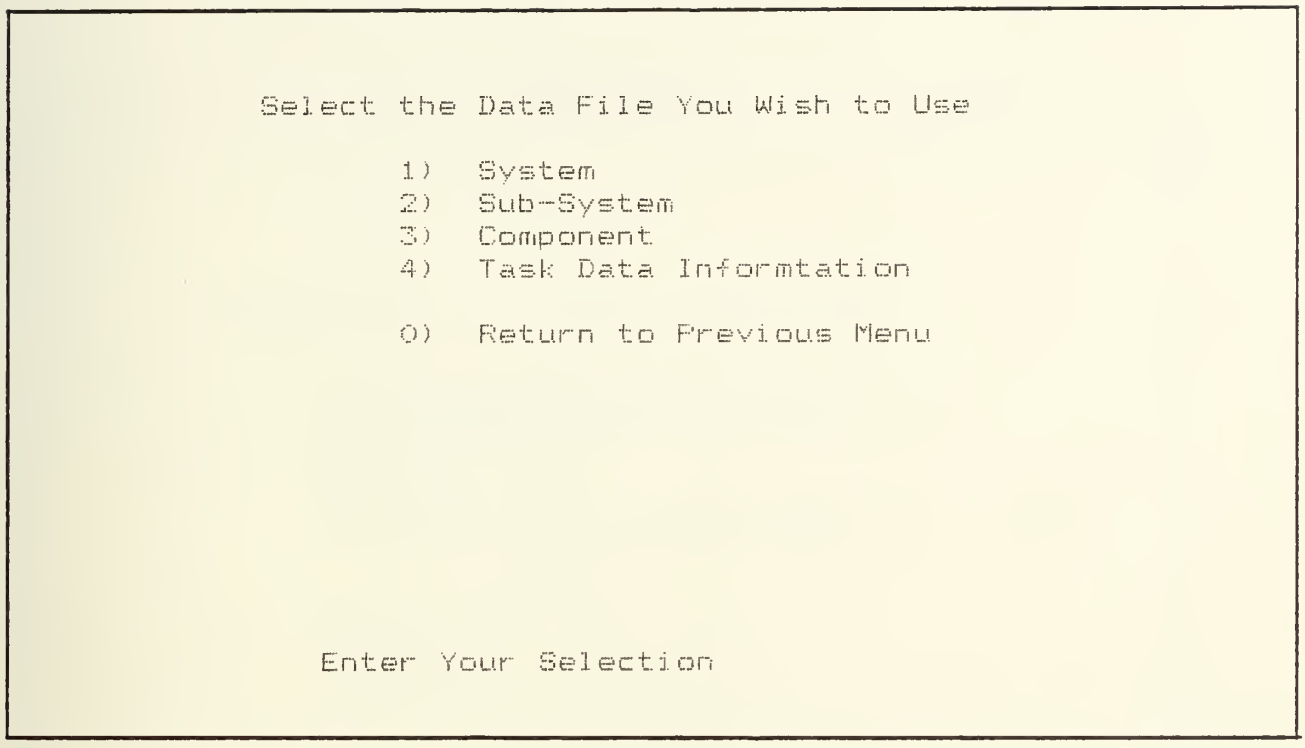


FIGURE C-13

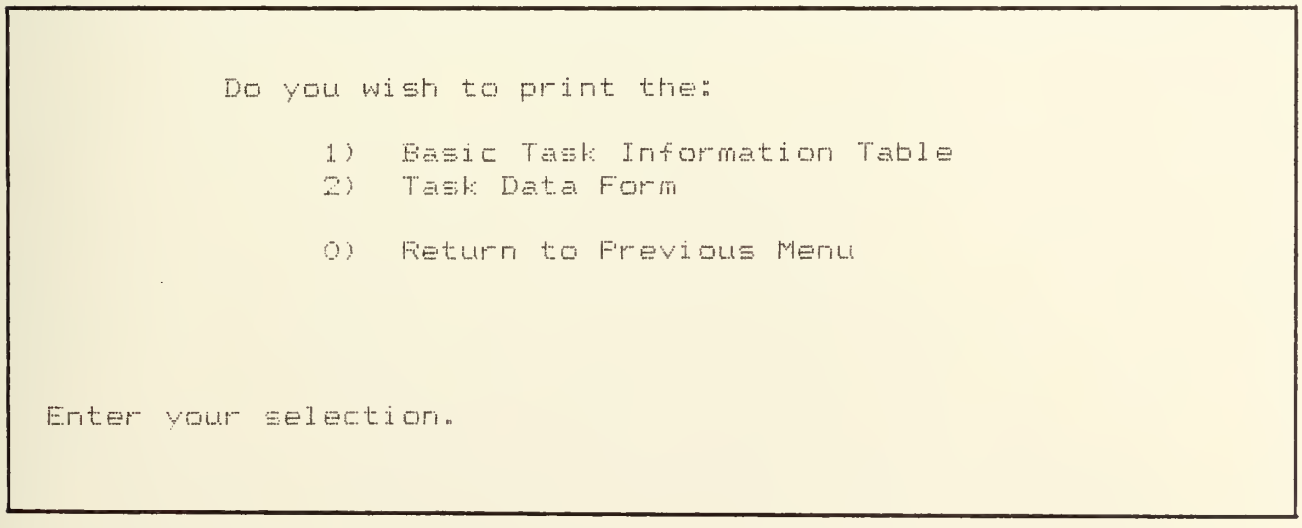
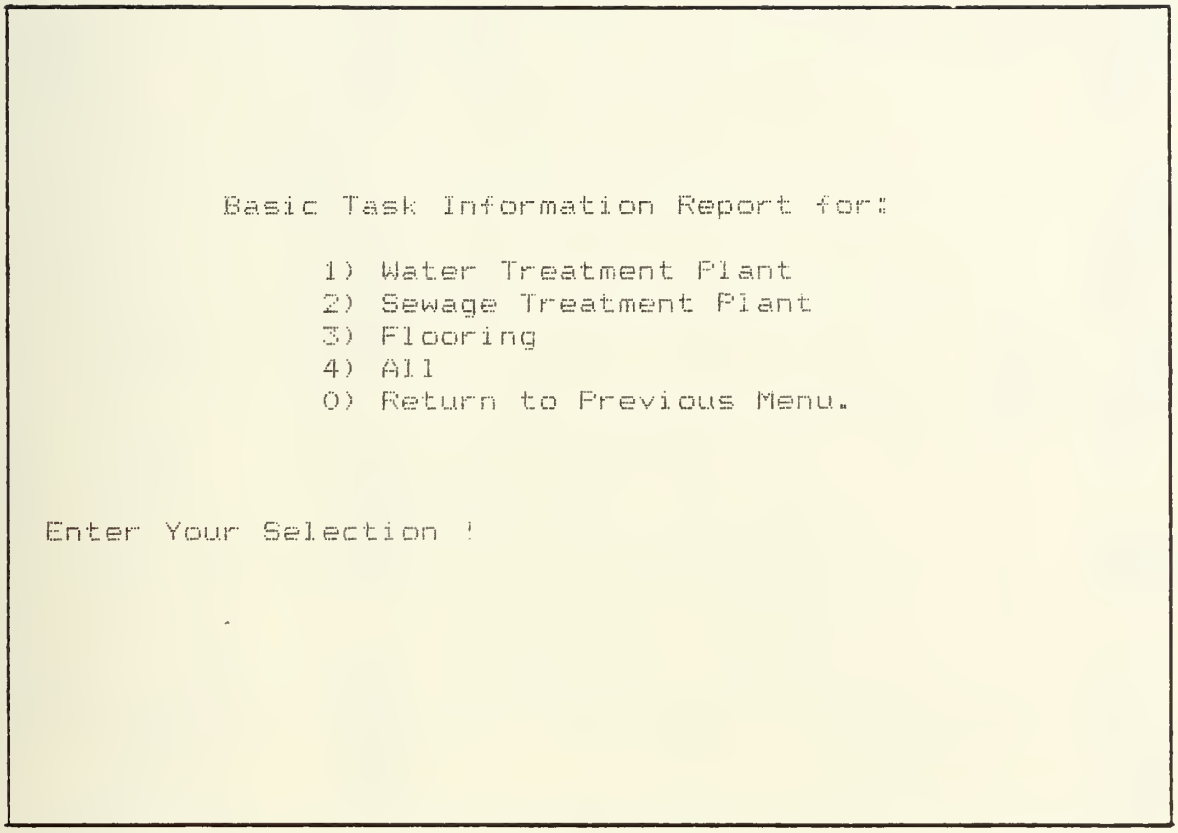


FIGURE C-14


Basic Task Information Report for:
1) Water Treatment Plant
2) Sewage Treatment Plant
3) Flooring
4) All
0) Return to Previous Menu.
Enter Your Selection !

TASK DATA FORM

Task Code: 0811102

Component: TANK-LESS WATER CLOSET System: SANITARY Subsystem: FIXTURES
Task Description: M/R UNPLUG CLOGGED LINE
Unit of Measure: 1-CT Frequency of Occurrence: H: 1.33 A: 1.67 L: 2.00
Persons per Team: 1 Task Duration: 1.391 Trade: 3
References: Labor: 2 Material: 1 Equipment: 1

Labor Resources		Material Resources				
Subtask Description	Labor Hrs	Description	Quantity	Unit Cost	Total Cost	Equiv Labor Hrs
REMOVE WATER CLOSET, UNPLUG LINE, RESET WATER CLOSET.	1.070	Material	0.00	0.00	1.31	0.0972
			0.00	0.00	0.33	0.0245

FIGURE C-16

SUMMARY

Resources	UOM	Direct	Indirect	Total
Labor	LH	1.070	0.321	1.391
Material	ELH	0.122	0.036	0.158
Equipment	ELH			1.391

Components Containing This Task: _____,

BASIC TASK INFORMATION TABLE

CASES TASK CODE	TASK DESCRIPTION	INDEX NO. TO UNIT OF MEASURE ROW	INDEX NO. TO TRADE	FREQUENCY OF OCCURRENCE			RESOURCES IN EQUIVALENT MAN HOURS		
				High	Average	Low	Labor	Material	Equipment
0811101	REPLACE FLUSH VALVE	1	3	8.0000	10.0000	12.0000	0.1170	0.0133	0.1170
0811102	UNPLUG CLOGGED LINE	1	3	1.3333	1.8887	2.0000	1.3910	0.1582	1.3910
0811103	OVERHAUL FLUSH VALVE	1	3	4.0000	5.0000	8.0000	0.5330	0.0810	0.5330
0811104	REPLACE WATER CLOSET	1	3	28.0000	35.0000	44.0000	2.0280	17.2999	1.0140
0811201	UNPLUG CLOGGED LINE	1	3	1.3333	1.8887	2.0000	1.3910	0.1582	1.3910
0811202	REPLACE WASHER IN BALL COCK	1	3	4.0000	5.0000	8.0000	0.1820	0.0212	0.1820
0811203	REPLACE WORN PARTS IN WATER CLOSET	1	3	13.0000	15.0000	17.0000	1.2000	0.1370	1.2090
0811204	INSTALL GASKET IN SPUD CONNECTION	1	3	17.0000	20.0000	23.0000	0.1300	0.0140	0.1300
0811205	REPLACE WATER CLOSET	1	3	28.0000	35.0000	44.0000	4.1080	24.8139	2.0540
0811301	REPLACE FLUSH VALVE	1	3	8.0000	7.0000	8.0000	0.1170	0.0133	0.1170
0811302	OVERHAUL FLUSH VALVE	1	3	1.0000	1.0000	1.0000	0.5330	0.0810	0.5330
0811303	UNPLUG LINE	1	3	4.0000	5.0000	8.0000	2.1190	0.2398	2.1190
0811304	REPLACE URINAL	1	3	28.0000	35.0000	44.0000	2.1190	30.3292	1.0595
0811401	REPLACE WASHER IN SPUD CONNECTION	1	3	8.0000	7.0000	8.0000	0.1300	0.0140	0.1300
0811402	REPLACE WASHER IN FAUCET	1	3	0.3333	0.5000	0.8887	0.1430	0.0188	0.1430
0811403	REPLACE SUPPORT RODS	1	3	8.0000	7.0000	8.0000	0.2470	0.0274	0.2470
0811404	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811405	CLEAN OUT STRAINER AND P TRAP	1	3	1.8887	2.0000	2.3333	0.4810	0.0540	0.4810
0811408	REPLACE LAVATORY	1	3	30.0000	40.0000	50.0000	2.0020	5.8311	1.0010
0811501	REPLACE WASHER IN SPUD CONNECTION	1	3	8.0000	7.0000	8.0000	0.1300	0.0140	0.1300
0811502	REPLACE WASHER IN FAUCET	1	3	0.3333	0.5000	0.8887	0.1430	0.0188	0.1430
0811503	REPLACE SUPPORT RODS	1	3	8.0000	7.0000	8.0000	0.2470	0.0274	0.2470
0811504	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811505	CLEAN OUT STRAINER AND P TRAP	1	3	1.8887	2.0000	2.3333	0.4810	0.0540	0.4810
0811508	REPLACE LAVATORY	1	3	28.0000	35.0000	44.0000	2.0020	11.8158	1.0010
0811601	REPLACE WASHER IN SPUD CONNECTION	1	3	8.0000	7.0000	8.0000	0.1300	0.0140	0.1300
0811602	REPLACE WASHER IN FAUCET	1	3	0.3333	0.5000	0.8887	0.1430	0.0188	0.1430
0811603	REPLACE SUPPORT RODS	1	3	8.0000	7.0000	8.0000	0.2470	0.0274	0.2470
0811604	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811605	CLEAN OUT STRAINER AND P TRAP	1	3	1.8887	2.0000	2.3333	0.4810	0.0540	0.4810
0811606	REPLACE LAVATORY	1	3	28.0000	35.0000	44.0000	2.0020	5.8311	1.0010
0811701	INSPECT/CLEAN SHOWER HEAD	1	3	1.8887	2.0000	2.3333	0.1170	0.0133	0.1170
0811702	REPLACE FAUCET WASHER	1	3	1.0000	1.0000	1.0000	0.1430	0.0188	0.1430
0811703	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811704	RESEAL	1	3	8.5000	10.0000	11.5000	0.7870	0.0875	0.7870
0811705	REPAIR DIVERTER VALVE	1	3	3.5000	4.0000	4.5000	1.0270	0.1158	1.0270
0811706	UNSTOP	1	3	1.8887	2.0000	2.3333	0.5720	0.0854	0.5720
0811707	REPLACE TUB	1	3	30.0000	40.0000	50.0000	3.3410	84.5939	1.6705
0811801	INSPECT/CLEAN SHOWER HEAD	1	3	1.8887	2.0000	2.3333	0.1170	0.0133	0.1170
0811802	REPLACE FAUCET WASHER	1	3	1.0000	1.0000	1.0000	0.1430	0.0188	0.1430
0811803	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811804	RESEAL	1	3	8.5000	10.0000	11.5000	0.7870	0.0875	0.7870
0811805	REPAIR DIVERTER VALVE	1	3	3.5000	4.0000	3.0000	1.0270	0.1158	1.0270
0811808	UNSTOP	1	3	1.8887	2.0000	2.3333	0.5720	0.0854	0.5720
0811807	REPLACE TUB	1	3	28.0000	35.0000	44.0000	3.3410	15.8878	1.6705
0811901	INSPECT/CLEAN SHOWER HEAD	1	3	1.8887	2.0000	2.3333	0.1170	0.0133	0.1170
0811902	REPLACE FAUCET WASHER	1	3	0.3333	0.5000	0.8887	0.1430	0.0188	0.1430
0811903	REPLACE FAUCETS	1	3	4.0000	5.0000	8.0000	0.8190	0.0928	0.8190
0811904	RESEAL	1	3	8.5000	10.0000	11.5000	0.7870	0.0875	0.7870
0811905	UNSTOP	1	3	1.8887	2.0000	2.3333	0.5720	0.0854	0.5720
0811906	REPLACE SHOWER	1	3	37.5000	50.0000	62.5000	98.9170	42.9712	49.4585

Figure C-15

FIGURE C-17

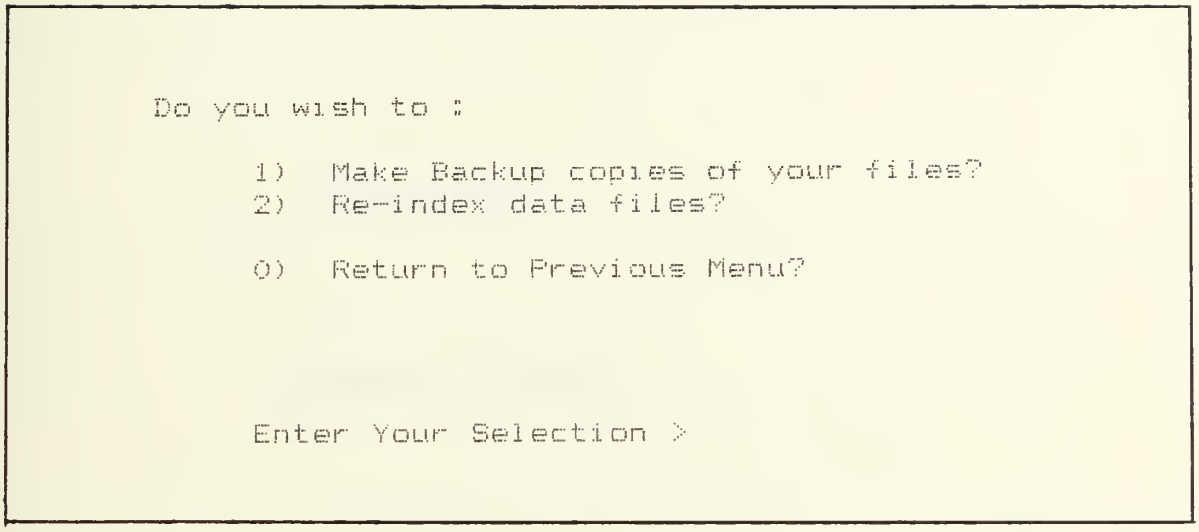
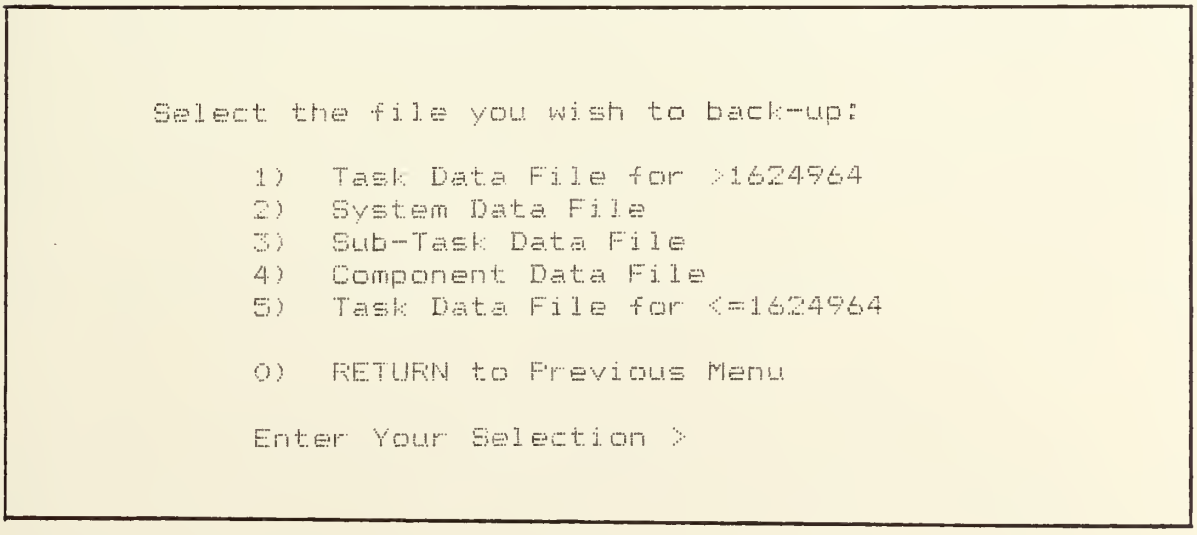


FIGURE C-18



Appendix D

SAMPLE LETTER

THE PENNSYLVANIA STATE UNIVERSITY
212 SACKETT BUILDING
UNIVERSITY PARK, PENNSYLVANIA 16802

College of Engineering
Department of Civil Engineering

Area Code 814
865-8391

February 14, 1985

Robert Olt
Lotepro Corp.
1140 Ave of the Americas
New York, NY 10035

Dear Mr. Olt:

Civil Engineering personnel at The Pennsylvania State University are performing a study of water and sewage treatment plants to develop factors to be used in determining annual maintenance and repair costs over the life of a facility. In order to accomplish this task, it is necessary to compile industry accepted standards for maintenance, repair and replacement costs attributable to facilities and equipment normally found in water and sewage treatment plants. It is intended that task statements will be developed for each of the maintenance/repair actions required. Data on the frequency of occurrence and time necessary for completion of a task will be gathered. These data will be used to generate predicted maintenance and repair costs for treatment plants of various sizes.

A second aspect of this study is to review the various management systems used to coordinate maintenance and repair activities. The revolutionary hardware advances recently made in the microcomputer industry have created a strong market for off-the-shelf software packages that can be used to manage the limited resources available for maintenance of facilities. Products and services such as yours are rapidly becoming available and once in place are an indispensable tool for plant managers.

Your firm is being contacted to obtain information on the products and services that you offer and a list of plants that are using any of these products. The principal researcher for this study is Mr. Roland Moreau, an Environmental Engineering graduate student in the Department of Civil Engineering. He can be reached by writing to the above address or by calling 814/865-1226 during afternoon hours. If you have any information that could be of value to him or would like any of your products or services included in the study, please do not hesitate to contact him. All sources of information will be kept confidential if requested.

Your assistance in this matter is greatly appreciated.

Sincerely,

David A. Long

David A. Long, P.E.
Professor of Civil Engineering

DAL/esh

Appendix E

LIST OF ESTIMATING REFERENCES

Appendix E
List of Estimating References

1. Model Task Listing from the Yonkers Joint Treatment Plant, Yonkers, New York dated 18 April 1985.

2. Model Task Listing from the New Rochelle Treatment Plant, New Rochelle, New York dated 18 April 1985.

3. Life Cycle Cost Data, by Alphonse J. Dell'Isola and Stephen J. Kirk; McGraw Hill Book Company, 1983.

4. EPS for Machine Shop, Machine Repairs Handbook; Army TB 420-12 dated April 1983.

5. Operations and Maintenance Manual for Sigsbee Park Sewage Treatment Plant, prepared by Briley, Wild & Associates, Inc. dated December 1983.

6. Operations and Maintenance Manual for Boca Chica Sewage Treatment Plant, prepared by Briley, Wild & Associates, Inc. dated December 1983.

7. EPS for Preventive/Recurring Maintenance Handbook; Army TB 420-34 dated March 1984.

8. EPS for Emergency/Service Handbook; Army TB 420-30 dated March 1984.

9. EPS for Pipefitting, Plumbing Handbook; Army TB 420-20 dated August 1983.

10. EPS for Electric, Electronic Handbook; Army TB 420-6 dated February 1982.

11 EPS for Unit Price Standards Handbook; Army TB 420-33 dated August 1983.

12. EPS for Sheet Metal, Structural Iron & Welding Handbook; Army TB 420-24 dated April 1979.

20. Interview of Plant Personnel at Bolton Point Water Treatment Plant, Ithaca, New York.

21. Interview of Plant Personnel of Onondaga County Metropolitan Water Board Water Treatment Plant, Oswego, New York.

22. Interview of Plant Personnel of Pennsylvania State University Wastewater Treatment Plant, University Park, Pennsylvania.

Appendix E
List of Estimating References

23. Interview of Plant Personnel of University Area Joint Authority Wastewater Treatment Plant, State College, Pennsylvania.

24. Interview of Plant Personnel of Mid Centre Authority Wastewater Treatment Plant, Milesburg, Pennsylvania.

25. Interview of Plant Personnel of Tyrone Regional Wastewater Treatment Plant, Tyrone, Pennsylvania.

30. Authors best engineering judgement.